Seed Supply Systems in Developing Countries

N. P. Louwaars with G. A. M. Marrewijk
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The Technical Centre for Agricultural and Rural Cooperation (CTA) was established in 1983 under the Lomé Convention between the African, Caribbean and Pacific (ACP) States and the European Union Member States.

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Wageningen Agricultural University wishes to develop and disseminate the scientific knowledge needed to sustainably supply society's demands for sufficient healthy food and a good environment for humans, animals and plants.

Its Department of Agronomy is one of about sixty University departments and was established after the merging, on 1 September 1992, of the former Department of Field Crops and Grassland Science and the Department of Tropical Crops. The science of Agronomy focuses on human intervention in agro-ecosystems through cropping techniques and management practices in order to obtain useful products for mankind and to promote sustainable use of land.

The Department of Agronomy works on solutions for agronomic problems by developing scientific knowledge about the ecology of (grass) vegetations, and the growth of crops for food, feed and raw material. By means of teaching and research, the Department aims to achieve a more thorough understanding of the functioning of agro-ecosystems and to contribute to the development of sustainable agriculture worldwide.

In teaching and research, the Department has the following aims:

i. to study the biological, physical and chemical aspects of the intervention by man in agro-ecosystems through cropping techniques and management practices, recognizing that these are also determined by socio-economic conditions;

ii. to integrate knowledge from other disciplines for the purpose of the analysis, improvement and design of cropping techniques and management practices, and of agro-ecosystems; and

iii. to study agro-ecosystems at two key aggregation levels (crop/vegetation and cropping system) while analysing also the sub-plant and overlying land-use system levels.
Preface

This book offers an overview of biological and technological aspects of seed supply and presents different seed supply systems which operate either individually or in combination. The local seed supply systems are reviewed: for most farmers in the tropics, such local systems are the main or only source of seed for the majority of crops. They are compared with the formal seed supply system which is a vertically-organised chain of operations from germplasm management through variety development to seed production, conditioning and distribution. Its operation is relatively similar throughout the world. Recent trends towards integration of these complementary systems are analysed. National seed policies and legislation have an important impact on the development of effective seed supply for the farmers.

That technical matters are related to a variety of non-technical topics is emphasised. The suitability of a certain seed supply system in a given situation depends on technical, social and economic considerations, the determination of which can be very localised. This is one of the major reasons why blue-prints for development are rarely effective. This book, therefore, is meant both for agronomists and social scientists working with farmers in tropical areas, and for planners and policy makers whose decisions can have an important impact on the availability of good quality seed.

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1 The importance of seed in agricultural production

Seed is defined here as any planting material for agricultural production. In this chapter, the importance of different seed-quality parameters is described and three seed supply systems are defined. A brief historical overview explains the context in which these systems developed: the systems themselves are discussed in later chapters. This chapter also presents the analysis of seed supply as a multidisciplinary study.

The seed

Seed as a necessary input

Seed is one of the basic inputs of any plant production activity. Historically, human use of seed marks the transition from nomadic food gathering to sedentary civilisations based on agriculture. This process occurred independently in different parts of the world: predominantly, in the basins and valleys of major rivers such as the Euphrates and Tigris, the Ganges, the Jiangtse, and rivers in Central America. Each of these early civilisations was based on very different crops; for example, wheat, barley and lentils in the Middle East, and maize in Central America. Similar to the early use of animals, one can speak of 'domestication' of crops. Characteristics of the wild plants that are not optimal for agricultural crop production are selected against and other characteristics are selected for. In this process various plants have changed considerably and new types have developed; some even having biological crossing barriers with their ancestors and thus developing into new species (e.g. wheat). Modern plant breeding and seed supply are just another phase in the same continuum of evolution and domestication.

The word 'seed' refers here to any part of a plant that is used for reproduction, both generative (true seed) and vegetative parts. The latter include vegetative reproductive organs that are very similar to true seeds but result from apomixis (e.g. Panicum and other grasses), and various other plant parts such as roots (cassava), tubers (potato), stems (cassava, sugar cane), branches (various fruit trees, sweet potato), leaves (various ornamentals), bulbs and rhizomes (strawberry). In botany, the words 'propagule' or 'diaspore' cover the whole range of reproductive organs of plants.

Although perennial- and some non-food crops are mentioned where appropriate, the focus of this book is on annual food crops. This is because of the marked difference (in both biological and organisational aspects of seed production and supply), between these crops and the perennial, often vegetatively-propagated, industrial cash crops like tea, rubber and cocoa, or seed-propagated crops such as oil palm. Seed supply for perennials is, by definition, a less-recurrent issue and the normally well-organised markets for these products imply involvement of the product trade organisations in seed production and supply.

The common term 'variety' is used in this document as a synonym for the scientifically more correct 'cultivar'. The taxonomic term 'cultivars will be indicated as 'botanical variety' to avoid misunderstanding.

Quality aspects

Knowledge of the various quality aspects of seeds greatly contributed to agricultural development in the past and will continue to play a major role in future enhancement of crop production. The quality characteristics can be divided into four major groups:

i. genetic seed quality;
ii. analytical seed quality;
iii. physiological seed quality; and
iv. sanitary seed quality.

Genetic seed quality is determined by those plant characteristics that result from the genetic potential of the embryo. It includes genetic variation within a seed lot. The manifestation of this genetic potential is influenced by agronomic practices and the ecological characteristics of the site where the seed is planted. Yield-determining components such as plant architecture, pest and disease resistance and harvest index, and culturally-important plant characteristics such as colour and taste of the commercial product are, to a large extent, genetically controlled. The genetic quality of a particular seed thus varies with the agro-ecological region, climatic conditions (e.g. a dry or an excessively wet season can seriously affect plant growth, and influence the genetic variation of a plant population), and the ethnic farming group. The quality sought varies for each end-use of the product (e.g. plantain; banana for cooking, frying, or beer making; beans for home consumption or marketing). Each farmer, therefore, may use different criteria in defining the genetic quality of a particular seed.

Analytical seed quality refers to the percentage of undamaged seed of the desired variety of a specific crop in a seed lot. Seed lots can be divided into good seed, inert matter (stones, straw, broken seeds) and foreign seeds (seeds
of other crops, of weeds, and/or other distinguishable varieties).

A special category is insect-damaged seed. In many cases such seed is rated in official seed tests as being good seed but it fails to germinate. Objective measurement of analytical seed quality is possible but the economic value of particular characteristics may differ depending on cultivation conditions. For example, the effects on production of a certain level of admixture with foreign seed in a seed lot may not be very damaging when all the seeds in the mixture are of the same age group; admixture with certain common weed seeds may not be noticed at all by a farmer. Should new weeds be introduced in his fields in this way, however, the economic damage may be significant.

Physiological seed quality refers to the ability of a seed to germinate at the desired time and to assure an adequate level of initial growth (vigour) of all essential parts of the seedling. These conditions are prerequisites for the development of a productive plant. Physiological quality of the seed includes germination capacity, viability, characteristics related to dormancy, and vigour; all are affected by:

- growing conditions, e.g. availability of sufficient moisture and nutrients and absence of serious diseases during the filling stages of the seed; absence of excessive rain during seed ripening and weathering (i.e. after-ripening on cut plants before threshing);
- harvesting and threshing methods, particularly with regard to mechanical damage;
- seed storage conditions; and
- the genetically controlled resistance to, and tolerance of, these stresses.

Four major factors affect the physiological quality of the seed in storage: duration, temperature, moisture and biotic factors (especially fungi, insects and rodents). The quality of a seed can only deteriorate during storage; except with regard to breaking dormancy, it will never improve with increased time in storage. In general, high moisture content and temperature stimulate metabolic processes in the seed and result in weight loss, accumulation of toxic metabolites and reduced seedling vigour. Finally, these affect viability and the seed dies. A rule of thumb is that the storage life of a seed lot is doubled by a one percent reduction in the seed moisture content or by reducing the storage temperature by five degrees Celsius. This is valid for many dry seeds within a certain range of seed moisture contents and temperatures (Harrington, 1963). Fungi thrive best at high moisture levels. They have direct detrimental effects through consumption of seed tissues and cause indirect harm through heating. Physiological seed quality can be measured by germination tests and other viability and vigour tests (Chapter 3).

Sanitary seed quality refers to the presence or absence of plant diseases in or on the seed. Storage fungi such as Aspergillus and Penicillium spp. affect physiological seed quality and their development is regulated by seed moisture content and temperature. Some diseases can be transmitted by seed without affecting seed viability or seedling vigour; because they can damage the plant in a later stage of development, however, their presence reduces overall seed quality. Examples are viruses that cause mosaics or leaf stripes, and smut fungi that affect the plants only after flowering. Other seed-borne diseases may impair crop establishment by affecting the seedlings.

Objective standards for sanitary seed quality are difficult to define. A minor infection of a seed lot, with a pathogen that is new to the area where the seed will be planted, can have disastrous consequences (phytosanitary control should prevent this). With another pathogen, on the other hand, heavier levels of infection could be acceptable where the crop would be infected anyway, through other sources. An example is the common bacterial blight (Xanthomonas phaseoli) in beans; it is seed-, soil- and air-transmitted. In an area where the soils are infected with these bacteria, some additional inoculum from the seed may result in a slight increase in disease incidence with an insignificant effect on yield. The introduction of inoculum into clean soil, however, may affect bean yields very significantly and for a long period. Production of guaranteed disease-free seed might be very difficult and too expensive compared with the minimal gains in crop productivity.

The use of seed, poor with respect to any of the above quality characteristics, can result in serious losses for the farmer. This may be evidenced by:

- poor crop stand as the result of low analytical, physiological or sanitary quality;
- increased disease pressure on the crop (low sanitary quality); or
- poor crop performance due to genetic seed quality parameters.

The last problem is particularly obvious when the variety is not adapted to the growing conditions. For example, high altitude maize grown in the lowlands results in tall plants and lodging. Significant losses due to poor genetic quality as the result of admixture of varieties may be less obvious, but similarly disastrous for the farmer, e.g. some red rice seeds in a white variety may seriously reduce the marketability of the resultant crop.

Seed supply systems

Most seed planted by farmers in developing regions comes from local sources, i.e. the farmer's own crop, neighbours, relatives, or from local markets. In some areas and for some crops, seed from outlets of the so called 'formal' seed sector is widely used. This sector produces seeds of selected cultivars (varieties) of which the analytical, physiological and, sometimes, sanitary qualities have been tested, and the genetic make-up of which is guaranteed through variety release and seed certification.

Three major groups of seed supply systems can be identified. They are defined as follows:
i. Local seed supply systems cover methods of local seed selection, production and diffusion. Cromwell (1992) describes these systems as traditional, informal, operating mainly at community level through exchange mechanisms and involving limited quantities per transaction. This corresponds with the ‘traditional seed sector’ (Camargo et al., 1989; Cromwell et al., 1992).

ii. Formal seed supply systems cover seed production and supply mechanisms that are ruled by defined methodologies and controlled (stages of) multiplication, and are backed by national legislation and international standardisation of methodologies (or, in the absence of de facto legislation, organised as if such laws did apply). In developing countries such systems are introduced, organised, (inter)national, and involve cash transactions and large uniform quantities. They are otherwise known as the ‘conventional seed sector’ of Camargo et al., (1989), the ‘organised seed sector’ (Chopra & Reusché, 1992) or the ‘institutional seed sector’.

iii. Integrated seed supply systems cover methodologies that aim to improve the local supply systems by ‘borrowing’ technologies and improvements from the formal sector and using informal channels (Louwaars, 1994a). This corresponds with the ‘non-conventional seed supply system’, introduced by Camargo et al., (1989) and incorporates ‘integrated plant breeding’, as introduced by Berg et al., (1991).

Since the early ‘sixties, many activities have been initiated to establish formal seed production systems in most developing countries. The main emphasis has been on spreading the ‘miracle seeds’ of the Green Revolution as quickly as possible. Between 1958 and 1987, the United States Agency for International Development (USAID) supported seed sectors in 57 countries. The FAO Seed Improvement and Development Programme (SIDP, 1972-1984) covered 60 countries, and the World Bank (IBRD) funded 13 national seed programmes and at least one hundred other seed-related projects in the decade following 1975. In addition to numerous potato projects (each with a seed component), in recent years the Dutch bilateral programmes have included support for the seed sectors of Kenya, Sri Lanka and Bangladesh and a seed unit at the International Centre for Agricultural Research for the Dry Areas (ICARDA), based in Syria.

Most aspects of formal seed production in developing countries remain in government hands. Some of the national seed companies are nominally private, but are heavily protected or subsidised by the respective governments. Only in a few countries are local private enterprises well established. In some countries, international private seed companies are active: often, for only a small number of crops such as hybrid maize, sorghum, pearl millet, sunflower and major vegetables.

Interest in integrated seed supply systems is a more recent phenomenon wherein the restructuring of the Seed Unit of the International Centre for Tropical Agriculture (CIAT), in Colombia, has played an important role. A novel interest in local and integrated seed supply is fuelled by the growing concern regarding world-wide loss of genetic diversity and the observation that genebanks may not be the ultimate solution to this problem (Louwaars, 1994b). (Chapter 6).

Whatever the source, farmers generally are very aware of the need to sow seed of the best quality available. This does not mean, however, that they prefer ‘official seed’ to that from local sources. Farmers’ priorities regarding quality may be better met by seed from local sources (Almekinders et al., 1994). The genetic quality of released varieties may not be adapted to the local agro-ecological conditions or specific consumer preferences in the area. It may be, even, that the analytical, physiological and sanitary properties of the ‘official seed’ are inferior to those of the local seed. Long and ill-designed distribution channels may cause deterioration of initially high-quality seed. Other considerations are:

- proximity of the supplier;
- timing of supply (shortly before the planting season);
- reliability of supply (quality and timeliness secured for next season too); and
- price of the seed (in relation to yield and produce price).

Seeds in rural development

The importance of seed as the carrier of important characteristics for crop production has been recognised since the early days of agriculture. Starting some 10,000 years ago, harvesting of seed from preferred plants has been the basis of crop domestication (Chapter 2) and, consequently, of present day agriculture.

Interest in seed as a major input and as an important vehicle to increase food production in the tropics, increased dramatically after plant breeding and variety testing had shown that new varieties are capable of producing many times the yields that were commonly obtained by local farmers. Research, based particularly on the staple food crops wheat and rice, was carried out by the international agricultural research centres (IARCs). These centres had been created by US-based foundations and, presently, are sponsored by several national governments and international institutions. In 1971 they joined to form the Consultative Group on International Agricultural Research (CGLAR).

Short-straw varieties with an increased harvest index (weight of harvestable product divided by weight of total plant dry matter) and capable of an increased response to added fertiliser, were developed for maximum yield potential. Controlled seed production was considered a major vehicle for transferring this technology to the farming communities. A completely new infrastructure had to be set up to facilitate this transfer. Because the yield potential of the new varieties could be obtained only with a high
fertiliser and biocide application, the seeds were often sold as a package in combination with such agrochemicals.

The Green Revolution

The adoption rate of these short-straw wheat and rice varieties was highest in the high potential areas and between 1965 and 1975. This period became known as the 'Green Revolution'. In combination with improved irrigation, chemical fertiliser and biocides, these varieties were the basis of tremendous yield increases; for rice, more especially in Southeast Asia and the Indian sub-continent. Even today a number of countries that were not importers of their staple food grain in the early sixties (e.g. India and Indonesia) now are self-sufficient or net exporters.

These modern varieties are genetically uniform in order to optimise the positive characteristics of the selected genotype and to design the optimum agronomic practices for the crop. On the negative side, however, their resistance can break down due to adaptation of the causal organism (mutation and subsequent selection).

Resistance to pests and diseases in local mixtures (landraces) often depends on a variety of resistance genes present in different plants in the same field. Resistant individuals in such populations reduce the rate at which a particular disease or pest spreads within the crop. On the other hand, susceptible individuals may be highly resistant to other strains of the causal organism or to other diseases, pests or abiotic stresses. Usually, such a landrace is not totally resistant but, also, the crop is never completely devastated by an endemic disease or pest. Introduced pests or diseases, however, can wipe out landraces as easily as they do modern varieties: examples are the spread of cassava mealy bug and cassava green spider mite in eastern Africa.

The rate of adaptation of a parasite increases in proportion to the availability of a uniform genotype acting as a selection substrate (i.e. host plant). A very successful variety-introduction programme (i.e. widespread farmer adoption), therefore, tends to induce the need for subsequent introductions of ever newer varieties at an increasing pace. This race against time is on-going although in some modern varieties multiple or polygenic (partial) resistances are being introduced in order to break out of this cycle. Another very common method to fight outbreaks of diseases and pests is the application of biocides. Farmers generally rely on credit to pay for the seed-fertiliser-biode package.

This system of high-input farming threatened the financial security of many small farmers. Often, a single poor harvest was enough to leave the farmer in debt that his land had to be sold. Also, many tenants were evicted from their land because the owners found it more profitable to work the land themselves and profit by an economy of scale (Lipton & Longhurst, 1985). Thus, many farmers became landless workers or migrated to the cities.

Risk-averse farmers who, in not switching immediately to the new technologies for fear of debt or because of more marginalized farming conditions, were faced with steadily decreasing prices for their produce at the farm gate. This was due to the increased supply by farmers in the better-endowed areas. Chambers and Chhidlyal (1983) stated that resource-rich farmers, whose conditions resemble those of research stations, are automatically favoured by the techniques developed at these stations. As early as the late 1960s, critics pointed out the social effects of the Green Revolution (Frankel, 1971).

Indeed, as a consequence of the Green Revolution the total food production in a number of Asian countries did increase dramatically (Dalrymple, 1986 a; b), but the cost was high: vulnerable crops replaced the lower yielding but more stable varieties (see Chapter 6); disparities between the few rich and the many poor, increased; and the use of vast amounts of agro-chemicals had serious ecological effects.

The programme which was initiated as a technological/political strategy for peace through the production of abundant amounts of food, (its main instigator, Dr. Norman Borlaug, received the 1970 Nobel Peace Prize for his work), also created significant social problems. These have added to existing problems, for example, in the Punjab in India and Pakistan where the Green Revolution has been particularly successful (Shiva, 1992). Lipton and Longhurst (1989) give an interesting overview of this development from an economic point of view.

Adapted strategies

With the world population continuing to grow and expansion of the land area under cultivation becoming more and more difficult, the pressure to increase production per unit area is also increasing. Nowadays, the methodologies of the Green Revolution are being adapted to some extent: integrated pest management (IPM) reduces the ecological pressures, and different types of farmer-participatory research are being carried out to improve the adaptation of new technologies. In addition, integrated seed supply systems have been initiated to increase the efficiency of seed-related activities. Farmers have noticed already that some local varieties fetch higher prices than do the improved ones and they have reverted to (or continued) planting them, e.g. red rice in West Africa and Indonesia (local market) or Basmati rice in Pakistan (local and export market).

An important question is why the yield increases of Southeast Asia and the Indian subcontinent have not been achieved in other areas, especially in tropical Africa where the population growth is most pronounced. Weisheit and Caviedes (1993) point at soil conditions and the fact that the major gains in Asia were made in the outer tropical and sub-tropical areas. Richards (1986) argues that the absence of landless rural poor in large parts of Africa and the fact that local varieties and cultivation methods are highly adapted to the prevailing ecological conditions, may be the cause. That large tracts of land with uniform and controlled ecological conditions (irrigation) are not widespread in
Africa, must also have contributed to this lack of success.

Implementation of modern plant breeding and seed production in the early stage of the Green Revolution is a clear example of how, in rural development, solving some problems can create others. The problems evolved from the too widespread introduction of a single technology (uniform genotype in a uniform package). With due regard to this lesson, the potential of these novel techniques is still valid: without a doubt, plant breeding is able to increase the yield potential of crops, and seed production and supply systems are necessary to transfer this technology to the farmers. For too long, however, plant breeding has been regarded as the only solution to global problems in agricultural production.

Recognition of the importance of plant selection for agricultural development is far from new. Farmers have been practising selection in their crops for millennia, and seed has travelled near and far due to human migration: step-by-step between neighbours and relatives, and through natural dispersal (wind, water, animals). Migrating farmers generally take seed of their landraces with them. With seed being their prime production factor, they cherish their own selections.

Most farmers search continuously for better technologies. In their quest they exchange seed and, in this way, seed has travelled over short distances. The subsequent introduction of the new seeds often starts with very small test plots and evaluation is done on various aspects including yield, disease resistance and consumption quality. In a remote part of Mali, such farmers' experimentation was found to be co-ordinated by the elderly men in the village (Stolzenbach, 1993).

Seeds supply:

a multidisciplinary approach

For a good understanding of local practices concerning seed selection and general cropping methodologies, it is necessary to combine insight into anthropological and sociological aspects with general agronomic, taxonomic, and edaphic knowledge. Seed production itself requires a sound understanding of genetics and selection methods along with knowledge of agronomy, phytopathology and (seed) technology. An institutional seed industry requires a sound business administration and logistical support. Contributions from all these fields together are needed to make seed an important tool in agricultural development and national (and international) food security.

Chapter 2 of this book describes the different methods of farmers' seed selection and the informal diffusion of the selected seed in different areas of the tropics. The institutional seed sector, from breeding to seed marketing, is discussed in Chapter 3. In the fourth chapter the limitations of both local and formal seed supply systems are discussed and ways to improve on the former type, with special reference to dissemination of new germplasm under low-input farming conditions, are described. Chapter 5 addresses seed policy and the development of the seed industry. Several seed-related issues that receive considerable attention internationally are discussed briefly in Chapter 6. Case studies are presented in the final chapter.

In this way, the book offers an overview of the various systems and ad hoc methods of seed supply in the tropics. It is done, however, without the pretence of completeness. Local seed supply is very location- and crop-specific and the formal seed sector uses very detailed rules and regulations which go beyond the scope of this book. The intention is to promote understanding of the mechanisms involved in the supply of seed with desired qualities, and the choices that farmers have to make. Inclusion of papers in the list of references at the end of each chapter does not automatically present a judgement on their scientific value and, despite considerable effort to the contrary, these lists are not comprehensive bibliographies on the topics of each chapter. This is mainly because a lot of information on seed systems is published only in 'grey' literature.

Early in the Green Revolution new seeds from the formal seed supply systems were called 'miracle' seeds and the sciences of plant breeding and seed production were given a 'miracle' status. It must be understood that, although new varieties are important in agricultural production, yield limits are not set only by the genetic and other qualities of the seed. Physical limitations such as soil degradation and moisture availability, and socio-economic limitations such as market organisation, land availability, tenure systems and increasing rural population also play major roles. In any situation, however, seeds are a low-cost input (compared with other external inputs e.g. agrochemicals) that can assist the farmer to increase or adapt his crop production to meet changing needs.

References in Chapter 1


2 Local seed supply systems

Breeding, production and marketing form the basis of both formal and local seed supply systems. This chapter covers discussions of these functions as they relate to local seed systems. Selection of seed sources, on-farm seed selection and farmer experimentation are shown to form the basis of breeding. The objectives and techniques of on-farm seed production are presented, and mechanisms of seed storage and distribution are analysed. These mechanisms are compared with early human activities that led to the domestication of our present food crops. The role of genetically-heterogeneous varieties in these systems is also discussed.

Crop domestication

The beginnings of agriculture

Early man was a food gatherer, hunter and fisherman. The first signs of agriculture appear only about ten thousand years ago. Why people started to plant crops and where they first did so is not certain but there are various theories based on archaeological, anthropological and/or plant-genetic findings - and a substantial amount of speculation. From sociology it is understood that the behaviour of present day human communities is very complex. Even more difficult, is to visualise pre-agricultural human communities of 10,000 years ago and to speculate regarding their reasons for making major behavioural changes. Theories about the transition from hunting/gathering to agricultural societies, with a concomitant shift from a (semi)-nomadic to a (semi)-sedentary way of life, have been described by Harlan (1975), Harlan and Steenber (1976), and Zeven and de Wet (1982). Some researchers believe that the transition was triggered by population pressures: others, by a certain readiness of the human mind to 'invent' the planting of crops. Yet others suggest that agriculture developed through a number of intermediate steps.

The population-pressure theory is difficult to prove. Cultural and natural causes (infanticide, geronticide, delayed marriage, wars, diseases and infant mortality) kept the population of gatherer-communities well below the carrying capacity of the range. Some of these factors still play an important role in some hunter/gatherer groups. On the other hand, in unmechanised agriculture, the carrying capacity of the land is limited largely by the availability of manpower. Increased population densities resulting from immigration or other causes may have increased the need for a more intensive use of the land and may, thus, have induced early agriculture. However, the converse of this, whereby the labour requirement of agriculture may have triggered population increases, could be equally valid. There is no proof for either theory. Changing ecological conditions and subsequent reduced food availability may have been important for the invention or development of agriculture. After a cold period prior to 12,500 BC, a warmer and dryer period 'must have placed prehistoric man under heavy environmental stress' (van Zinderen Bakker, 1976), pressuring them to produce food more intensively. This is the theory of 'agriculture by need'. Harlan (1975) postulates, however, that only the more flourishing populations may have had the time and energy to develop complicated and labour-intensive systems such as agriculture; hence, the theory of agriculture resulting from culture. In yielding more food per man per day, agriculture, allowed specialisation of artisans, craftsmen and administrators, resulting, in turn, in more complex civilisations.

The theory that agriculture was 'invented' suggests that agricultural technology originated at a single site, after which the techniques spread throughout the world. Archaeological evidence from various continents indicates, however, that agriculture probably developed in different areas in much the same period and involved many different plant species.

The most likely concept is that agriculture developed as an extension of the food gathering behaviour and involved a number of transitional techniques such as:

- burning range lands to suppress broad-leaved plants and to encourage subsequent growth of grasses for raising cattle or promoting wildlife;
- selective weeding to allow useful plants to grow (especially near the homesteads); and
- re-planting of plant parts after consumption of the edible parts (e.g. the tops of yams) thus securing survival of the plant.

Man-made waste heaps probably were an important source of knowledge regarding parts of plants that could be used for propagation. These so-called 'camp followers' have developed into important crops. In a later stage of agricultural development weeds, being plants that also thrive in disturbed soils, were co-domesticated along with crops. Some weeds, having been tolerated in wheat crops, eventually developed into crops: examples are rye and oats.
Changes in crops

Gathering grain from wild plants generally involves shaking the panicles into deep baskets or sweeping flat baskets through the field in order to collect dehiscent grains or spikelets. Nature tends to favour plants with many seeds that are small enough to be carried over large distances yet large enough to produce vigorous seedlings. Delayed and irregular seed germination (dormancy) is a natural mechanism of wild plants that secures survival of the species. Farmers, on the other hand, want plump seeds that remain on the plant until harvested and which germinate at a particular desired time.

Selection for these characteristics can be natural, unintentional or deliberate: day-length insensitivity is selected for naturally in environments where the sensitive plants do not flower; non-shattering plants are selected if harvesting is delayed until all dehiscent fruits have dropped; and a limited maturation period is automatically selected if harvesting is done as a single operation instead of several repeated operations during the maturation range of the population. These last two situations are examples of unintentional human selection (as opposed to natural selection, in which man has no influence). Deliberate human selection occurs when seeds with preferred characteristics (size, colour, etc.) are planted and, also, when seeds are collected from plants with preferred characteristics (e.g. plant architecture, size of cereal heads). Thereafter, the progression to modern plant breeding activities is not unduly long.

Domestication of wild plants through all forms of selection has affected significant changes in plants:

- **Plant habit** may change such that useful parts are more productive (e.g. increased root thickness in carrot, cob size of maize and fruit size in melons); consumption quality is improved (e.g. reduction of internode length in cabbage and lettuce) or individuals are better adapted to conditions of higher plant density (e.g. upright leaves in many species, reduced tillering in cereals and reduced branching in sunflower).

- **Changes in flowering biology** commonly relate to fertilization mechanisms and may involve: a reduced ability to cross-fertilize (e.g. the development of hemaphrodite instead of dioecious papayas); loss of self-incompatibility (e.g. self-fertilizing African yam, derived from a very limited introduction which only survived because very weak S-alleles were selected); and a shift from heterostyly to homostyly (e.g. wild tomatoes are generally cross fertilizing; most cultivars are selfing due to reduced style length). Self-fertilizing crops are more easily selected than are cross-fertilizing crops. If vegetative propagation is possible, domestication is even easier and can be done in a single selection operation. This has been done with many fruit trees, e.g. olive and apple. Fertility can be lost in the process of domestication. Polyploidy, which generally produces larger (harvestable) plant organs, can also result in reduced fertility and, sometimes, necessitates vegetative propagation as in the case of the triploid cultivated banana and plantain clones. Reduced dispersal mechanisms include, for example, a reduction of shattering in cereals and legumes.

- **Consumption quality** concerns characteristics such as strings in mangoes, tannins in many fruits, alkaloids in root crops, endosperm types of maize and malting quality of barley. Often, however, any reduction in toxic substances such as tannins and alkaloids is also preferred by plant predators. Domestication, therefore, can cause dependence of the crop plant on human protection.

- **Examples of physiological changes** include: reductions in seed dormancy (groundnut), photoperiod sensitivity (sunflower), and cold tolerance (maize); increased harvest index (almost all crops); and changes in maturity period. As illustrated above, domestication can reduce resistance to pathogens and predators (reduction in toxic compounds, thornless plants) and, where domestication has been limited to a small population of wild plants, it can reduce genetic variation (hence resistance). Domestication, therefore, can result in vulnerable crops.

Maintenance of the changes

Isolation of specifically-adapted populations is the basis for further differentiation of various types within a species. Crosses with surrounding wild populations could nullify the effects of human selection. The following isolation mechanisms can be identified:

- **geographic isolation**, due to migration or to specific adaptation of a crop, e.g. in hilly areas;
- **temporal isolation** applies when the crop is selected to flower in a different period of the year;
- **genetic isolation**, for example, in changes from cross fertilization to selfing, and the continuous practice of vegetative propagation reducing the incidence of flowering; and
- **cultural isolation** as when each tribe plants different selections.

Adaptation to the new environment through selection further differentiates types within a crop species.

Human migration and trade have been the major vehicles of germplasm distribution over long distances and of isolating plant populations. In early times of human settlement, barley spread from its source in the Middle East to Ethiopia and to present day Pakistan. More recently, the western colonisers have been instrumental in spreading a large number of crops all over the world. A well known example is the 'Bounty's' transportation of bread-fruit from the Pacific to the West Indies in order to produce cheap food for plantation labourers. The movements of many plants have been described and the sources of many crops can be traced. Botanical gardens, established in Europe from the
mid-16th century onwards (Pisa, Padua, Leipzig, Leiden and Kew), played an important role as intermediaries and as sources of information about the possible use of different plants. *Hevea brasiliensis* had been collected in South America but its use in supplying rubber was identified in Kew after which seedlings were transported to the East Indies and Malaya. Botanical gardens in the former colonies such as Sri Lanka (Peradeniya), Indonesia (Bogor), Trinidad, and Mauritius served both as collection points of local germplasm and as recipients of foreign germplasm. They became the early centres of agronomic research in the tropics. In this manner, continuous transportation of germplasm has led to the situation in which the most important foods in many countries are of alien origin. This is true especially of cash crops. Examples are: potato in Europe; cassava and cacao in Africa; and rubber in Asia. All originate in South America.

This isolation from their original habitat had two distinct consequences with regard to plant diseases and pests. In their new environments, the crops thrive well in the absence of the diseases and pests but they lose the competitive forces that have protected them throughout evolution. When a disease or pest manages to follow the crop, for example by uncontrolled exchange of seeds or food trade between regions, its impact may be devastating.

In modern times, plant breeders (especially those of the international agricultural research centres of the CGIAR and national genebanks), are responsible for an ever-increasing spread of germplasm to all corners of the world. Plant quarantine, to protect crops from imported pests and diseases, becomes more and more difficult (Bos & Vermeulen, 1991). This transporting of plants across continents resulted initially in an increased genetic variation in the transported crops due to selection in a different environment. In contrast, however, much present day agricultural research results in the spread of new and uniform varieties of crops to more and more farmer's fields all over the world. The effect is reduced global genetic diversity. This global loss of genetic variation is a growing concern (Chapter 6).

**Sources of genetic diversity**

Both isolation and adaptation through selection merely reduce the genetic diversity and would have had little impact on crops if genetic differentiation mechanisms did not exist. Mutations, including genome aberrations such as polyploidy, and introgression with wild relatives or with different populations within the same species, contributed to the development of plant genetic variation before deliberate recombination developed in modern plant breeding.

![Image: Initial distribution of sorghum from central Africa and the resulting differences in spikelet types (adapted from Harlan et al, 1976 and House, 1985).](image_url)
Sorghum (Fig. 2.1), which was domesticated in central Africa, is one such example. *Caudatum* types developed in central Africa; *Kafir* types evolved in southern Africa; *Guinea* types that originated in western Africa were taken to eastern and southern Africa at a later date; *Dura* types developed in northern India and, later, were re-introduced into (northern) Africa. Meanwhile, *Kaojiang* types formed in China. When such very different populations of sorghum meet, as happened in Ethiopia, variation is greatly enhanced and possibilities for selection and adaptation increase.

**Geographic centres of diversity**

Genetic variation is the basis for plant breeding. The earliest researchers in the field of plant origins were interested particularly in the geography of (cultivated) plants: Von Humboldt (Essai sur la Géographie des Plantes, 1807), De Candolle (Géographie Botanique Raisonnée, 1855) and Darwin (Variation of animals and plants under domestication, 1868). Vavilov (1926) furthered these views by including, in the analysis, genetic variation within species. He presented his famous eight centres of origin based on the patterns of genetic diversity in crops and the presence of wild relatives (Fig. 2.2):

<table>
<thead>
<tr>
<th>Region</th>
<th>Some important crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. China</td>
<td>soya bean, tea</td>
</tr>
<tr>
<td>II. India/Indo-Malaya</td>
<td>rice, sugar cane, banana</td>
</tr>
<tr>
<td>III. Central Asia</td>
<td>wheat, rye, flax, pea, onion, carrot</td>
</tr>
<tr>
<td>IV. Near East</td>
<td>wheat, barley, rye, oats, cabbage, melon</td>
</tr>
<tr>
<td>V. Mediterranean coasts</td>
<td>wheat, barley, cabbage, olive, boot</td>
</tr>
<tr>
<td>VI. Ethiopia</td>
<td>coffee</td>
</tr>
<tr>
<td>VII. S. Mexico/C. America</td>
<td>maize, bean, chilli, cotton, tomato</td>
</tr>
<tr>
<td>VIII S. America (Andes)</td>
<td>potato, bean, tobacco, pumpkin</td>
</tr>
<tr>
<td>VIIIa. S. America (Brazil)</td>
<td>groundnut, cassava, rubber, cocoa</td>
</tr>
</tbody>
</table>

**Plate 2.1** Even outside the primary centres of diversity important genetic variation can be found in local seed systems (Courtesy CPRO-DLO Wageningen)
Plate 2.2: Soya bean crop on the bunds of paddy fields to cater for seed need in the dry season (courtesy of C. van Santen)

Plate 2.3: In Indonesia, soyabean can be grown in paddy fields during the dry season, and upland during the wet season. Seed moves from farmer to farmer according to their seasonal needs (courtesy of C. van Santen).
Despite current disputes as to whether these are, indeed, centres of origin or centres of domestication of the particular crops, the practical implication of Vavilov's analysis is extremely important. Critics of the centres of origin concept and, consequently, major contributors to the further conceptualisation of the centres of diversity concept, include Zhukovsky's (1964) 'megacentres'. Zeven and de Wet (1982) discuss genetic diversity per region. This avoids the scientific 'tribal battles'. The importance of the concept of the centres of diversity is that they correspond with the areas where the crop has been grown for a long time and where co-evolution with various diseases has resulted in a balance between pathogenic diversity and resistance mechanisms. The centres, therefore, are important sources of resistance genes. As Frankel and Soule (1981) illustrate, this is not always true: Andean potatoes are highly susceptible to Phytophthora infestans which developed in Mexico together with other Solanum species; germplasm collection in the eastern Himalayas yielded maize samples with important resistances to leaf blight, downy mildew and corn borer - far from the Mexican centre of diversity of the crop.

A concept useful from a practical point of view is the differentiation between primary and secondary centres of diversity. The former is the geographical area where a high genetic diversity in the crop species is combined with presence of wild relatives, including the supposed parental species. Often, such a primary centre is considered to be the origin of the species or the area of primary domestication. A secondary centre of diversity is any area where the crop has been grown extensively for a lengthy period and where local adaptation has developed a wide range of genetic diversity which is different from the range in the primary centre. Both primary and secondary centres of diversity are very valuable as sources of useful alleles for further breeding.

Seed sources for the farmer

Farmers' values

Seed is a primordial input for crop production, it is the embodiment of past harvests and the promise of future ones (Tripp, 1993). The genetic composition of the seed determines the potential economic yield of the crop and it carries the genetic properties that are important for the farmer. These are:

- **Production values**: yield potential and stability, i.e. crop tolerance of biotic and abiotic stresses that are common under the specific edaphic and climatic conditions of the farmer (drought, water-logging, wind, diseases, pests, weeds) and within his economic and managerial capabilities (labour availability, cropping systems, etc.); value of secondary products (e.g. straw).
- **Consumption values**: shape, taste, colour and suitability for different methods of preparation: baking, boiling, frying, roasting or porridge.
- **Economic values**, e.g. early maturity (production in the 'hungry' season), production for market demand, longevity in storage, appearance of the produce and length of the harvesting period.
- **Cultural values**: in some communities crop and product appearances are related to certain beliefs and rituals.

In selecting their seed, farmers have to balance this range of values. Often it is women farmers who take charge in seed selection (rice: Unnevehr & Stanford, 1985, vegetables: Samuddin, 1992). They have a wide range of selection criteria and concentrate on family consumption needs (Fresco, 1985). Male farmers tend to put more emphasis on market-related characteristics (Sperling, 1992).

Risk avoidance is an important economic objective of most farmers. The choice of varieties and mixtures can play an important role in yield stability. Seeds from unknown or distant sources risk being poor performers under the farmer's particular agro-ecological conditions whereas modern varieties, which supposedly have a greater yield potential, are thought to have a higher standard deviation of yield over time (years). This formula is a good measure of yield stability. In order to optimise their research efficiency (public sector) or financial returns (private sector), plant breeders deliberately select for wide adaptation, i.e. a high average yield over a wide range of environments. Farmers, on the other hand, are not specifically interested in wide adaptation but in repeatedly high average yields (stability) in their own fields. Biologically there may be a significant overlap between adaptation and stability, but they are not synonymous.

Binswanger and Barah (1980) presented a theoretical model in which farmers are expected to strike a balance between average yield and standard deviation for yield (risk), i.e. risk aversion per se cannot be the only explanation for variety preference. Cromwell and Wiggins (1993) stress that the aversion small farmers feel towards risk should not be regarded as a sign of conservatism. Risk-avoiding techniques are normally associated with active farmers' experimentation.

On-farm seed sources

The values presented above cover a wide range of more or less clearly-defined genetic characteristics that the seed has to carry along with the purely productivity-related physical, physiological and sanitary qualities. Access to seed that can fulfil these various requirements is an important precondition for improving crop production.

In most cases, crops grown under the particular ecological conditions of the farmers do fulfil many of the above requirements. Continuous natural and human selection, (deliberate or unintentional) will mould the genetics of the crop to become optimally adapted to the particular farming conditions and human preferences. Selection of seed from the farmer's own crop is widespread and, as long as external conditions remain roughly the same, this 'farmer's conservatism' is often the best way. In
addition to these factors related to crop production, the farmer's prestige can be related either to saving the traditional varieties (Poey, 1982) or to introducing a new variety into a community (author's personal experience in Uganda).

In addition to this tendency to conserve what was found to be good, there are various reasons why a farmer will endeavour to improve his cropping. They include changes in the external situation (e.g. as increased population pressure implying the need for increased area output and land degradation causing problems in maintaining reasonable production levels). In general, farmers aim to improve yields or reduce labour input in order to increase their standard of living. Planting of improved seed can be an important and readily-accessible method of improving cropping output or efficiency. Many farmers will select fields, individual plants or individual panicles from which seed for next season's planting can be harvested (Almekinders et al., 1994) or they may travel far to obtain exotic planting material which is then multiplied on farm (Fresco, 1985).

Off-farm seed sources

For various reasons a farmer may search for other seed sources:

- If the field of another farmer shows promise of genetic improvements or good quality seed.
- If the farmer was unable to keep his own seed for technical reasons: crop failure, seed storage problems (e.g. weevils in cereals, or viability problems in soya bean), or displacement due to civil strife.
- For economic reasons, e.g. potato farmers in Ecuador reportedly do not keep their own seed very systematically because fresh seed tubers are available throughout the year and storage would mean an opportunity cost (Crisman & Lequillas, 1989). Poverty may force the farmer to sell his entire harvest. Sometimes, seed production is too complicated, making purchased seed economically unattractive (vegetables).

The most common external sources of seed are the following:

- Relatives, friends and neighbours: in some areas these collectively form the next most important seed source after farm-saved seed (Cromwell, 1992). Such seed is often obtained without cash transactions.
- 'Local seed farmers', i.e. those farmers who become known in the community as suppliers of good seed. There are few reported cases (Wardell, 1993) but the situation may not be rare (van Amstel, pers. comm.). In seed diffusion studies these farmers are called key diffusers; often, they are influential people in the community (Green, 1987). They may operate in the local non-cash system or they may become part of a commercial but informal seed system (Scheidegger et al., 1989).
- 'Seed areas', i.e. villages or areas that have (developed) specific comparative advantages for seed production. Linnemann & Siemonsma (1989) report on a specific village in Indonesia that produces soya bean seed in the rice growing season to supply a whole region. In Nepal and in the Andes, potato farmers at high altitudes generally supply seed to farmers in the lower areas (Rhoades, 1990). A (seed) trader is often necessary as intermediary and to provide the transport (Rhoades, 1985).
- Local grain and/or fresh vegetable markets are an important source of seed if all other sources fail or if the farmer is not very particular regarding his source preference (beans in East Africa, Grisley, 1993; vegetables in Sri Lanka, Louwaars, 1985).
- Local seed markets can develop. The source of the seed is often unknown and the quality may vary greatly, especially where storage conditions and packaging is poor. Louwaars (1985) reports unlabelled vegetable seed of reasonable quality in hardware shops in Kandy, Sri Lanka. This situation is common throughout Asia but much less widespread in Africa.
- Development projects or retail outlets of the formal seed sector provide Certified Seed of scientifically-bred varieties (Chapter 3).

Little systematic quantitative research has been done on seed sources and the reasons for the farmers' particular choices. It is clear from the literature that one cannot generalise about how the farmer in the tropics chooses seed to plant. Seed supply strategies depend on the cultural background of the farmer, on the biological and economic features of the crops and on individual parameters.

The poorest farmers are reported to have serious difficulty in saving their own seed and often have to rely on the food grain market for their seed needs (Ferguson et al., 1990; Sperling et al., 1993). Waaijenberg (1994) reports that only 15 of the 39 farmers surveyed in a Kenyan coastal region had kept sufficient quantities of maize seed even after a rather good production season. 'After a bad year farmers have to plant any seed that they can lay their hands on.'

Methods of farmer's selection

Botanical factors

For most crops, farmers can reserve part of their harvest for the next planting season. Planting material, thus, is the same product as that for consumption, e.g. cereals, legumes, potato. For some other crops, planting material consists of parts that can be harvested as required, e.g. cassava, sweet potato and pineapple. A third category comprises those crops in which some part of the otherwise consumable harvest has to be sacrificed intentionally in order to produce seeds. Examples are okra, and cucurbits (whole fruit), lettuce, cabbage, radish, carrot and onion (whole plant). With respect to the last three crops, the
roots or bulbs can be lifted, selected and replanted in specific seed fields. In contrast, okra and cabbage plants have to remain where they are planted, a fact which may complicate land-use planning for the next season. In crops such as tomato and chilli, consumable parts and mature seeds are produced at the same time.

This last distinction between crops is important. When the seed can be used for consumption (e.g. cereals and pulses), the farmer has an option to plant grain from another source (e.g. the market) or to cut the seed in periods of famine. A decision to leave certain onion or cabbage plants in the field for seed production eliminates the consumption option and seed production becomes a very intentional operation. For cereals and pulses, seed is selected during or after harvesting whereas, for other crops, single plant selection is more common.

Botanical factors affect the ease with which good quality seed can be produced on farm. They are important, therefore, for determining the economic feasibility of commercial seed production (Chapter 4).

Plant genetic factors
From a biological/genetic point of view, it is important to know the mode of selection used by farmers. Options include:
i. planting separate seed production plots which are closely observed throughout the cropping season and rogued of unwanted types;
ii. selecting in the production field throughout the cropping season;
iii. selecting in the production field shortly before harvesting;
iv. selecting after harvest (on seed characteristics only); and
v. random collection of seed from the bulked harvest.

Option (i) is a form of intentional seed production which offers a good opportunity for selection. If used for cross-fertilizing crops, small isolated on-farm seed production plots will induce inbreeding and genetic drift. Hindagala (pers. comm.) reported that, in Sri Lanka, those problems occur in local seed production of maize; the crop is of very minor importance there. This method, however, is used successfully when seed storage causes insurmountable problems. Out-of-season groundnut production for seed has been reported from the Philippines (Boeckel & Gbiriche, 1983) and for soya bean in Indonesia (Linnemann & Siemonsma, 1989). Separate seed production fields are also found as part of farmers’ experimentation with new germplasm introductions (e.g. beans in Rwanda). New types are not introduced directly into the varietal mixtures but are planted in separate plots for observation throughout the season. Once an introduction proves to be favourable its seed is harvested and mixed with other lines for crop production. Also, small seed production plots may be used to multiply seed that is in too short supply for food crop production.

Option (ii). Also an intentional local seed selection system; this is not normal practice in most areas because it requires a high level of organisation. Selected plants have to be marked and collected at the end of the season. This approach can result in a rather strict selection and narrowing down of populations. A more common method that is related to this system is the in-season selection of a plot where plants are vigorous and healthy and which, subsequently, is harvested separately for seed. A survey by Janssen et al., (1992) showed that 31% of bean farmers in Colombia apply this method, whereas 69% select after harvest (Option iv).

Option (iii). Selection and collection of seed immediately before harvesting allows the farmer to observe the general plant characteristics and those of its seed. This method is widely adopted for many crops.

An unusual method was reported by León (1964): Superior maca (Lepidium meyenii) plants were selected at harvesting, the roots transplanted to a well-manured area close to the home and the plants allowed to flower and produce seed. Such a method allows thorough plant selection, including selection against the production of strongly-dehiscent seeds.

Option (iv). Selection of planting material on the basis of seed characteristics only, is also widely applied (especially in crops which display clear differences in shape, size and colour). Such seed characteristics may correspond to general agronomic features. In Rwanda, farmer seed specialists regard small-seeded beans to be better adapted to less favourable conditions. Often, this is true. Seed characteristics are important for marketability of the produce. Post-harvest selection of seed for market production, therefore, can be very effective although its effectiveness for agronomic value depends on the variability within each seed type.

Option (v). This option relies on natural selection. Plants that produce the greatest percentage of viable seeds after storage (the fittest under such farming conditions) will be represented most in the next generation. A number of natural selection pressures work in the same direction as would selection by man: resistance to stress, whether biotic (pests, diseases, weeds) or abiotic (drought, low fertility), is selected for by nature whenever required. For some other characteristics, selection by man clearly counters natural selection, e.g. indelisible and large grains.

Genetic variation
The basis of selection is genetic variation. Generally, almost all fields planted with seed from local sources show a high degree of heterogeneity (i.e. variation between individual plants) and degrees of heterozygosity (i.e. allelic variation within a plant) that vary with the breeding behaviour of the crop.

Local varieties, generally, harbour wide genetic variation whereas most modern cultivars are developed such
that they are as uniform as possible in order to increase their yield potential and to comply with legal requirements (Chapters 3 and 5). Normally, heterogeneity results in a less than maximum yield potential but can contribute significantly to yield stability (Clawson, 1985). Several different genotypes in a field insure against fluctuating conditions such as differences in total rainfall, rain distribution or disease epidemics in subsequent seasons. Whether or not this genetic variation in local varieties is maintained intentionally for reasons of yield stability, or yield stability is simply the result of seed selection, is debatable. Many researchers report that farmers are aware of the need to maintain variation for yield stability. Others claim that economics, rather than risk aversion, is the basis of most of the farming practices of small farmers.

Other reasons for maintaining high levels of variability in the farmers' fields are to balance the labour requirements of the crop(s) and for the expedience of prolonging the harvest season. Early-maturing types are required to supply the food needs early in the season and late-maturing types to reduce storage problems. This variation may be maintained within a variety or plot, or between different plots within the farm. To even out labour (and machine operation) requirements over a longer period is a major reason why commercial farmers in America plant different maize hybrids on their farms (Pioneer, 1990). For various crops in the tropics, different types are required to fulfill multiple distinct uses. An example is sorghum: it may be consumed raw or boiled, it may be ground or brewed; it has medicinal and dyeing properties, or may used for building material, fodder, brooms and fuel. Different plant parts are used for different purposes and different selections have been made during the process of domestization to provide the various products (de Wet et al., 1976). Merrick (1990) describes multiple uses for squash crops in Mexico: flowers, immature and mature fruits, seeds, tendrils, leaves and vine tips are consumed; mature fruits are used for fodder, and dried rinds as containers. Another clear example is the differentiation in the species *Brassica oleracea* to provide edible stems (caul), leaves (various cabbage types) and leafy side shoots (Brussels sprouts). These different uses require genetic variability within species.

In a survey carried out in the Amazon basin of Peru, an average of 12 cassava cultivars was found per garden (Boote, 1984); 12-50 distinct types of landraces occur in Malawi (Martin & Adams, 1987). Voss (1987) found that only 9% of bean farmers surveyed in Rwanda grow one mixture, while the majority grow three or more mixtures of this crop.

**Selection**

For various reasons, maintenance of diversity is often intentional. A good example is that of barley selection in a remote valley in western Nepal where, immediately before harvesting, experienced women collect seed for the next cropping season. They do not pick only the best-looking ears with the greatest number or the fattest grains, but sample the variation of the whole field, picking from tall and short stems, long and short ears, fat and smaller seeds (Ceccarelli, pers. comm.). A plausible explanation is that, apart from selecting for yield stability, the women are also avoiding the possible selection for unwarranted agronomic characteristics. For example, picking only long ears with fat grains could result in plants with reduced tillering, increased height (competition) and/or a gradually retarded maturity.

Methods and objectives of selection generally have either a cultural (product-oriented) or an agronomic (genetic-oriented) basis.

**Cultural basis for selection**

Like other farming practices, selection of heterogeneity sometimes is rooted in a complex act of cultural legends and beliefs that may not always have an agronomic basis, but often do. Nazarea-Sandoval (1992) describes this for sweet potato production in certain areas of Mindanao, in the Philippines. Farmers dig grasses and leaves into the hills before planting. The purpose is to aid (metaphorically) the sweet potato plant: in reality, however, it does provide organic fertilizer for decomposition. Ashes from the kitchen stove applied to give the root the 'right texture' may also be an indispensable source of potash and micro nutrients for the crop. Various ideas of 'things to mix' result in the planting of three different sweet potato cuttings per hill to induce better growth (and to maintain diversity and yield stability). Nazarea-Sandoval claims that the farmers do not hold to the idea of a 'best' cultivation practice nor do they believe that an ideal sweet potato variety exists and should be sought. A result is that, because selection for such an ideotype is not done, genetic variation is maintained.

Johannesen (1982) describes the attitude of Indian farmers in Guatemala: they tend to avoid challenging the 'maize' spirit by refraining from various practices such as planting at inauspicious times.

Another anthropologically-advanced belief in some cultures is that seed of the major food crops is a cultural heritage. Farmers are not very likely, therefore, to change plant populations through rigorous selection or by replacing them with introductions. This is reported to be the case for potatoes in certain areas of Peru (Zimmerer, 1988). Richards (1985) reports that in Liberia, on the other hand, farmers change their seed on average every five years while growing an average of 2.4 distinct types per household and 20-30 distinct types per village. In these cultures, visitors who bring some 'new' rice seed as a gift are highly esteemed. Such a gift is a sign that the visitor is willing to share a very personal possession with the host.

Zimmerer (1991) found that variation within potato fields in the Andes has a cultural basis. Although many different mixtures were recorded, the level of cultivar diversity within the fields was found to be remarkably
constant. He concluded, therefore, that the farmers in the area share a culturally-formed perception of diversity within fields.

**Genetic basis for selection**

The influence of cultural beliefs on agronomic practices, as described above, corresponds to a very limited knowledge of pollination and other basic biological phenomena. Other authors, however, report practices that do appear to have a sound scientific foundation: Squire (1940) reports that rice farmers in Sierra Leone select their seed from the central portion of the field, thereby avoiding introgression from other landraces and, especially, from wild Oryza species around the field (in Richards, 1985). In the same area, however, Richards (1985) found that rice farmers had no notion of cross-fertilization. Hernandez (1985) describes methods for maintaining maize populations in northwestern Mexico that include both temporal and spatial isolation of different types and Johannessen (1982) found that similar methods were employed in Guatemala. Tanzanian farmers deliberately separate hybrid maize fields from those of local maize in order to protect the local types (Friis Hansen, 1988). Unintentional isolation of different types occurs when selections are cultivated in different seasons. Harlan et al., (1973) describe two very distinct sorghum types in West Africa: a 180 days-maturation population is grown during the rainy season and a 90 days-maturation type is planted in water-retentive soils after the rains.

**Objectives of selection**

Farmers generally select for a number of different characteristics at the same time. Of these, agronomic features often score relatively low. The sweet potatoes referred to above were selected mainly for the morphological (basic structure and appearance) and gastronomic features of the tubers. Important agronomic features such as number and size of the roots were clearly secondary considerations.

Although yield is one of the important criteria for which bean farmers in Africa select, of equal importance are taste, cooking quality, and marketability (Ferguson and Sprecher, 1987). Potato farmers in the Andes group the tubers according to use-categories (culinary, storage, market qualities); for seed they merely select for colour diversity within each category. Various investigations revealed that the preferred types of potato were consistently among the least common in the field. It may be deduced, therefore, that directed selection is not common in these polycultivar fields and that selection is performed only between, and not among, the major use-category groups (Zimmerer, 1991). In the Andes region, Zimmerer (1992) also found that farmers select strongly for popping bean (a particular type of Phaseolus vulgaris which is rotated rather than boiled). Popping beans are intercropped with common beans with which they may cross at a rate of up to 5%, resulting in various types of popping bean that are distinguishable, from other popping beans and from common bean landraces with which they are mixed, only by their seed morphology. Plant characteristics for which farmers do not select are not different from one popping bean to the other or even between the popping bean and the common bean. The agronomic qualities and genetic composition of the populations, therefore, are also expected to be the same except for the distinctive 'popping' characteristic.

All these examples suggest that determining the criteria for selection by end-use of the product combined with a lack of selection for agronomic characteristics, will result in genetic variation in agronomic characteristics that may contribute to an increased yield stability.

Sterling, who worked extensively in Rwanda with what she calls 'local seed experts', expressed an opposite view (Sterling et al., 1993). She found that the women assign very specific values to each of the many bean types in the various mixtures they grow. They know whether each type is adapted to shading (cultivation under banana), tolerant of poorer soils, is a top yielder in good soils, or whether it is prone to disease infections under high rainfall conditions. This local knowledge is based on assessment of the value of individual constituents of mixtures and not on each mixture as a whole. The selection of seed for planting, therefore, involves the deliberate mixing of specific types of beans depending on the plot that will be planted to beans that season. Sorghum farmers in Burkina Faso are also reported to have ear-marked specific varieties for different edaphic conditions (Reusché, pers. comm.). Box (1984) found that cassava farmers in the Dominican Republic deliberately change their varieties according to the level of land degradation.

**Seed storage**

Pests, diseases and physiological deterioration can seriously reduce the quantity and quality of harvested products. Seed stock that has to be stored until the following planting season is particularly vulnerable. Janssen et al., (1992) conducted a survey of bean growers in Colombia. Their results showed that inability to preserve seed from weevil attack was the major reason why approximately one third of the interviewed farmers purchased seed.

Throughout the world various storage methods have been developed locally for individual crops: often, unthreshed heads (sorghum), ears (wheat), panicles (rice) and cobs (maize) and unhulled seeds (groundnut and bean) store better than the same seeds, cleaned. Commonly, seed is stored in the farmer's kitchen where smoke from the hearth protects it from weevils and moths and, possibly, from excessive humidity (Kone, 1993). Potato farmers in Nepal (Rheadees et al., 1988) and the mountainous regions of central Africa, use herbs to protect seed potatoes from insects. Layers of leaves of Plagia frosa, powder of Cissus quadrangularis and Cassia nigrans, and leaves or extracts of Neon (Azadirachta indica) are used in various parts of the world (Kone, 1993; Gwinne et al., 1991). Ash, mixed in with bean or cowpea seeds, can offer some protection
against bruchid damage but an application of vegetable oil can be as effective as chemical insecticides such as Lindane (van Rheenen et al., 1983).

Storage in airtight containers is common practice and storage of sorghum and sesame seeds in calabashes sealed with mud has been reported. Soft-drink bottles and glass jars are used for small quantities of vegetable seed (e.g. in Sri Lanka) and, in Somalia and Ethiopia, seed is buried in deep pits in the ground. Storage in airtight containers gives perfect protection against insect devastation since the living seeds and the few insects which may be stored with the seed will consume the available oxygen. This, however, is only feasible when the seed can be dried very well before storage.

Cassava crops can be left in the field. Sorghum seed can, in effect, also be 'stored' in the field in that seed can be harvested from the ratoon (Fresco, 1986). From a seed technology point of view though, there are major concerns about the physiological and, especially, the sanitary quality of the seed obtained from a ratoon. To avoid major storage problems, however, the method can be useful.

For security reasons it is sometimes necessary to store seed in the home (Rhoades et al., 1988).

Dissemination of seed

Selection of seed by farmers would be a rather static activity if the results were not shared with others and if the seed was not spread near and far.

The level of interest in agricultural experimentation and its organisation within the village community are important factors that affect the adoption of germplasm of cultivated crops. Social mobility within and between (tribal) societies, and disasters such as famine and war, contribute significantly to the spread of plant material.

Grisey (1993) noted that within communities in western Uganda diffusion of potentially valuable germplasm is important. Social recognition is gained thereby.

Considerable cultural differences exist with regard to the value of sharing seed (see Richards above) and regarding farmer experimentation in different communities. Ferguson and Precher (1987) report that most bean farmers in Malawi and the great lakes area of central Africa are innovators who look out for new germplasm and willingly try new varieties. Of 220 bean samples collected, one quarter had been grown by the farmers for less than five years. In other areas, experimentation is done only by the elders of the village and the research is cloaked in secrecy; the spread of both methodology and results, therefore, is slow (Richards, pers. comm.).

Local seed dissemination can spread varieties over remarkably vast areas. The rice variety 'Mahsur' was tested at research stations in Andhra Pradesh, southern India. Though rejected by the breeders responsible, it was acceptable to a labourer at the station who planted a sample in his own field. The variety spread more than one thousand kilometres through Orissa and Bihar to Uttar Pradesh in the north, West Bengal in the east and Madhya Pradesh in Central India. It was reported to be the third most important rice variety in the country (Maurya, 1989). 'Pajam' rice, introduced in Bangladesh in 1965, was never released but by 1978 had become the most important rice variety in that country (Pray & Rameswaram, 1991). The cowpea variety 'African Red' was grown as a component in a rotation scheme in the May Pen tobacco growing district of Jamaica. After termination of the (tobacco) experiments 'African Red' was adopted by the farmers and it quickly spread throughout the area (van Marrewijk, pers. comm.).

The potency of local diffusion mechanisms can be established best when new varieties are introduced into an area. Green (1987) describes this for the (local) rice variety 'Pokhreni Masino' which spread, from the central valley of Nepal to the bordering hills, by both formal and informal means. A survey in one administrative unit in the Koshi Hills showed that 94% of the farmers who grew the variety had obtained it from other farmers. Only 42% of the farmers passed it on to others (key diffusers). That these farmers had a more developed commitment to development, was in no way related to farm size or other parameters. In the majority of cases, diffusion occurred within the ethnic group and within a distance of one hour's walk. In the 10 years between 1976 and 1985, the area planted to Pokhreni Masino rice increased by a factor of 50.

Sperling & Loevschnin (1993) state that poorer farmers are unlikely to be main diffusers of bean varieties in Rwanda. Their economic inaccessibility makes it difficult to keep seed for their next planting, let alone have seed for others.

In southern Mexico the very best ears of maize are auctioned and the revenue donated to the Church. Many other ceremonies are linked to the growing, selecting and diffusing of maize seed (Johannessen, 1982).

The existence of seed-producing regions or villages greatly influences the mobility of seed and varieties. The more commercial the seed trade, the more it will respond to farmers' needs through experimentation and selection.

Crop failure due to natural causes or wars can result in seed shortages and the need to find any kind (including new kinds) of planting material. Farmers may travel far to find seed which may then turn out not to be optimally adapted to their conditions. The introduced material may, however, harbour some useful characteristics that can become incorporated in the local germplasm though mechanical mixing or introgression. Wars can also have major effects on seed availability over large areas (Chapter 6). Over the past few years, rehabilitation programmes have imported, annually, more than a thousand tonnes of seed into Sudan and Ethiopia from neighbouring Kenya and Uganda. Some of these exotic varieties may establish themselves in the new surroundings.

The general conclusion of the studies on informal seed diffusion is that the speed and effectiveness of the system depends largely on the quality of the variety to be diffused; kinship relationships; the existence of a culture of local agricultural experimentation; and the economic stability of the farming enterprise.
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3 Formal seed supply systems

Intensified agriculture calls for improved seed. The production and supply of certified and tested seed of verified varieties is the result of a chain of activities known as the formal seed supply system. The breeding section of this chain comprises three major elements: plant breeding, giving rise to different varieties and hybrids; variety release; and maintenance of varietal identity and purity. Plant breeding can produce superior varieties through recombination and subsequent selection of as many positive characteristics as possible in one genotype or one population (especially in cross-fertilizing crops). Multiplying that genotype under strict supervision will result in a crop production field with a maximum number of plants with those positive traits. The genetic homogeneity of the crop allows the application of uniform cultural practices at the optimum time. Varietal uniformity is, thus, both a result and an objective of modern plant breeding. The relevance of modern plant breeding activities is valid as long as the breeding objectives are well defined and sufficient genetic variation can be obtained (Chapters 4 and 6). Organisations responsible for the supply, distribution and marketing of quality-controlled seed, often backed by formal policies and legislation, make up the formal seed sector.

Framework of interrelated institutions

An extensive organisation is required to ensure that the small amount of seed of a new and tested variety can be bulked to amounts that can be distributed to farmers. The stages in seed handling, from breeding to planting for crop production, are called the seed chain. As with any chain, the seed chain is as strong as its weakest link. Good plant breeding will not be maximised if seed-conditioning facilities are not in place. Seed production relies on sound marketing with reliable sales forecasts and effective selling and delivery.

The formal seed sector is influenced greatly by a large number of policies in the fields of agriculture, trade and economics; and also by concomitant legislation. Such influences may affect the seed chain directly or may have a significant impact on the organisational framework within which the seed chain operates. Various international organisations aim their activities at streamlining methods of seed production and control in order to facilitate international seed trade:

- the Organisation for Economic Cooperation and Development (OECD), based in Paris, France, has responsibility for designing uniform methods of inspection and labelling;
- the International Seed Testing Association (ISTA), designs uniform seed-testing methods and grants licenses to laboratories that meet its standards;
- the Union for the Protection of New Varieties of Plants (UPOV), based in Geneva, Switzerland, was established to promote plant variety protection and to realise uniform legislation in this field; and
- various commercial seed trade organisations such as the Fédération Internationale des Semences (FIS) and the Association International des Sélectionneurs pour la protection des obtentions végétales (ASSINSEL).

Other international organisations aim to facilitate the international transfer of germplasm. Of note are the institutes of the Consultative Group on International Agricultural Research (CGIAR) and their collaborating national institutes. The International Plant Genetic Resources Institute (IPGRI), based in Rome, Italy (formerly, the International Board for Plant Genetic Resources (IBPGR)), was established to coordinate the collection, documentation, storage and distribution of germplasm. The Food and Agriculture Organization of the United Nations (FAO) also plays an important role in this field.

Each link of the chain is of equal importance. Research policies, agricultural (price) policies and general business policies all affect the whole seed chain.

Research policies affect the budgets of national research organisations and hence their efforts to supply the chain with good starting material. Through their relation to national policies for food security, industrial development (oil crops for soap factories, edible oil plants, intensive animal production, fibres etc.) and general trade policies (promotion or limitation of imports of agricultural commodities or the development of export markets), they greatly affect how budgets are spent. Agricultural price policies affect crop production profitability which, in turn, influences the potential and the effective demand for seeds from the formal sector. National business policies promote or discourage the possibilities for developing private businesses (including seed companies) through currency controls, wage regulations, taxes and subsidies, etc.

Since many different ministries are involved in a developing seed industry, clear national policy on seed is
required to guide both public and private initiatives in the seed sector. Often, this policy includes the institution of a National Seed Board to streamline the policy-making operations in changing situations and to organise the various control mechanisms. Such a seed policy could also develop or monitor a seed-quality control infrastructure, such as a National Seed Certification Service. At some stage, such a certification service requires the backing of a specific law which spells out the duties of the various parties involved in the seed chain. A seed law should specify the requirements for variety release, the methods and rules regarding seed certification (including, for example, a generation system, field inspection, seed testing and labelling) and standards for punishment of those who violate the law. Plant variety protection is usually organised under a separate law. In some cases, it is covered by the seed law itself. More details on seed legislation are presented in Chapter 5.

A very important aspect of any seed policy is how, ideally, the seed chain should be organised, i.e. who should do what. Basically, there are two opposing views on seed industry development; the developmental and the commercial (Louwaars, 1990). In the former, seed supply is seen as a method to channel the benefits of modern agricultural research to the farmers. Seed plays a crucial role in agricultural development and, therefore, could be offered at subsidised prices in order to increase the adoption rate of the new technology and to increase national food production. On the other hand, seed production can be seen also as a productive operation which should be run as a business. Investment in purchasing good seed is recouped by the individual farmers and subsidies would only distort the system. Farmers are best off with a healthy and commercially-sound seed industry and governments should facilitate the establishment and operation of this industry by reducing economic and bureaucratic barriers. In practice, these two extremes in seed policy result in very different seed-supply organisations.

In short, therefore, the seed sector is a very complex chain of events that aims to supply seed of high quality in the right place at the right time. Seed quality refers to both the genetic quality, which should be as close as possible to the quality of the released sample of the variety, and to the optimum physical, physiological and sanitary condition. For the organisation of a sustainable seed chain, the price of the seed should be high enough to cover all the costs and it should be low enough to attract sufficient buyers. See Table 3.1.

**Plate 3.1** Creation of variability: crossing of wheat (courtesy CPB-CTA Wageningen)

### Self-fertilizing crops

Though the term 'self-pollinated crop' is used widely, the authors prefer the more correct 'self-fertilizing' crop. Many crops show a very high degree of selfing; absolutely self-fertilizing species are very rare. Plants, that under normal conditions show a selfing rate of 95% or more, are regarded as being self-fertile. In this category are found, for example, most cereals (rice, wheat and finger millet) most legume crops (common bean, soya bean, cowpea and groundnut) and several vegetables (tomato and lettuce).

Breeding of self-fertilizing crops normally involves crossing and repeated selection in the segregating population. The end result is, in most cases, a so-called 'pure-line variety' which comprises genetically-identical plants. Genetic impurities such as segregants and mutants should be removed continually (rogued). An alternative method involves the combination of a number of pure lines into a multi-line variety. This is done to introduce some variability into the variety to improve yield stability against diseases and non-biotic stresses and may result thus in improved yield stability. The individual lines should be maintained separately to avoid genetic drift. If the lines are to be produced separately during the Foundation-, Registered- or Certified Seed stages, the components have to

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**Plant breeding, variety release and maintenance**

Plant breeding involves five main steps:

- identification of objectives;
- creation of variability (introduction, recombination);
- selection of preferred types;
- finishing off of the variety; and
- variety maintenance.

Outlining the theoretical background of genetics, statistics and the different methodologies used in plant breeding, is beyond the scope of this book. Some terminology and some varietal characteristics relevant to the plant breeder, however, are discussed briefly.

It is important for a seed producer to know the mating system of his seed crop because it determines the required isolation distances, the uniformity standards and, possibly, the use of insecticides. Production of hybrid seed is a special case.
Table 3.1: The seed chain and related policies, legislation and organisation patterns

<table>
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<td>industrial development policy</td>
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| Seed Use | Farmer uptake: | | |
|----------|----------------|-----------------||
| Seed price policy | various classes of farmers i.e. | | |
| Agricultural input price policy | regarding farm size, level of | | |
| Agricultural product price policy | commercialisation | | |
| | acceptance depending on seed | | |
| | qualities, availability & price | | |
pass separate distinctness, uniformity and stability (DUS) tests. Also, individual lines can be mixed at the Breeder Seed stage but by then some natural selection during the different seed production stages might have occurred.

**Cross-fertilizing crops**
Crops that in the majority of cases do not fertilize themselves are referred to as being cross-fertile. In this group are completely cross-fertilizing crops, such as oil palm and papaya, where most plants are either male or female (dioecy) and crops where other mechanisms prevent selfing and promote cross-fertilization. An example of the latter type is cabbage; pollen gametes and egg cells from the same plant or clone, are incompatible. Other cross-fertilizing crops do not have strict barriers against selfing. A seed producer has to know whether his cross-fertilizing seed crops are wind- or insect-pollinated. Examples of the former are maize and pearl millet. Sunflower, sesame, onions, cucumber, cabbages and carrots, normally, are insect-pollinated.

To prevent contamination of a seed crop by unwanted cross-fertilization, seed plots have to be distantly isolated from commercial crop fields and seed plots of other varieties, and from intercrossable wild species. With wind-pollinated crops the danger of contamination is determined largely by the strength and direction of the wind, and by hills, hedges and other topographical features that, in acting as windbreaks, reduce pollen dispersal. Though very small pollen grains can be transported hundreds of kilometres, wind usually does not carry large quantities of pollen far. Insects (e.g. bees, bumble bees and flies) normally confine themselves to small foraging areas but when they are forced to migrate to new fields (by reduced flowering) they constitute a great danger of contamination. Seed plots of insect-pollinated plants (e.g. sunflower), therefore, are planted at greater isolation distances than are those of wind-pollinated crops. To produce seed of insect-pollinated crops requires very particular care, such as the banning of insecticide spraying during the whole flowering period to protect the pollinating insect species.

Normally, germplasm of cross-fertilizing crops is kept as populations. Breeding depends on selection within the populations or crossing between populations. The resultant product is a selection, a composite, a synthetic, an inbred line or a hybrid.

A *selection* is a group of plants selected from a population. Often, the population is a locally-adapted landrace or an open-pollinated variety.

A *composite* is a variety obtained after combining a number of different populations. Selection within the resulting population is necessary to obtain an acceptable level of uniformity for the most important characteristics such as plant height, maturity period and consumer quality. The resultant composite variety is then multiplied as an open-pollinated variety.

A *synthetic* is a variety obtained after combining a number of well-defined, carefully-selected, often inbred genotypes that are expected to generate a significant level of heterosis (the hybrid vigour that occurs when unrelated materials are combined). A synthetic can be multiplied as an open-pollinated variety but can be constituted fresh as long as the parent genotypes are maintained.

An *inbred line* of a cross-fertilizing crop is a nearly-uniform population obtained after repeated, forced selfing. It can be compared genetically with a pure line of a self-fertilizing crop. Inbred lines of cross-fertilizing crops often are weak due to inbreeding depression. Normally, therefore, inbreds cannot be developed into commercial varieties though large differences in inbreeding effects can occur between crops and between different characteristics within a crop.

A *hybrid* is the first generation from a cross between two different parents. A hybrid variety is a commercial variety obtained after controlled crossing of two, often inbred, parents that are selected to give optimum hybrid vigour in the offspring. Different types of hybrids are discussed below.

**Semi cross-fertilizing crops**
Crops that normally have a natural out-crossing percentage of 5-50% are called 'semi-cross fertilizers'. Examples are sorghum, sesame, okra, hot and sweet pepper, eggplant, yardlong bean and some barley varieties. Under normal climatic conditions, most flowers of these crops are self-fertilizing but out-crossing occurs at too high a frequency to classify them as self-fertilizers. Varieties are normally of the pure-line type (as with self-fertilizers) but the contamination risks are so high that isolation distances are similar to those of cross-fertilizing crops.

**Hybrids**
One of the main difficulties associated with hybrid seed production is the avoidance of unwanted selfing in the seed parent. Preventative methods that may be employed include:

- the use of gynogenous seed parents (e.g. glasshouse cucumbers);
- emasculating, i.e. the removal of the anthers or male inflorescences before pollen is shed (e.g. tomato and maize);
- male sterility, i.e. nuclear or cytoplasmic genetic factors, causing absence or non-release of viable pollen (e.g. onion, sunflower and rice); and
- self-incompatibility, i.e. genetically controlled inability of gametes and egg cells to mate (e.g. cabbage).

The type of hybrid that is developed, is determined by the number and genetic constitution of the parents:

**Single-cross hybrid.** This is the first generation of a cross between two inbred lines, giving maximum heterosis and a uniform offspring. Often, seed yields are low because the seed parent is a weak inbred line. Since the parents are genetically uniform, the range of
flowering periods is relatively short. Synchronisation of pollen shedding (by the pollen parent) and the receptive period of the stigma (of the seed parent) is thus of utmost importance. Often, this requires staggered planting of the two parent lines.

**Three-way-cross hybrid.** This is the first generation of a cross between an inbred line and a single-cross hybrid, wherein the single-cross parent normally is used as the seed parent. A three-way-cross hybrid, therefore, is based on three inbred lines. The level of heterosis and uniformity can be slightly less than that of a single-cross hybrid but, with the seed parent already being a hybrid, seed yields can be greatly improved. Synchronisation can still be a problem since both parents are genetically uniform.

**Double-cross hybrid.** This is the first generation of a cross between two single-cross hybrids. It allows the seed producer to have two vigorous parents in the production field of the Certified Seed. To produce Foundation Seed requires the production of two different single crosses. Maintenance breeding involves handling four inbred parents in isolation. Depending on the genetic distance of the different inbred lines, a double-cross hybrid can still have good uniformity. Synchronisation remains an important issue since, yet again, the parents in a double-cross are genetically uniform.

**Top-cross hybrid.** This is the first generation of a cross between an inbred line and a population (often an open-pollinated variety). When the population is the pollen parent, synchronisation problems are less important since the variability in the population will secure pollen availability over an extended period of time. Generally, a top-cross hybrid variety does not have the level of uniformity that distinguishes most hybrid varieties from composites and synthetics, but a certain level of heterosis can still be achieved.

**Varietal hybrid.** This is the first generation of a cross between two open-pollinated varieties, selected for their combining ability. Such varietal hybrids are produced as a first step in developing other types of hybrids and in preparing the seed production infrastructure for hybrid seed production. They are not very popular, because the extra seed production cost often outweighs the expected yield increase at the farmers’ level. Fig. 3.1 shows the effects of hybrid/population type on the genetic heterogeneity and level of heterozygosity in the variety.

Since hybrids are combinations of carefully selected parents that produce positive interactions at the molecular level and result in higher performance potentials, it may be expected that farmer-saved seed of hybrids generally will result in poor crops. The heterosis and uniformity of the crop is lost and many characteristics revert to those of the weak inbred parents. Where farmers do plant F2-generation maize, they tend to plant many seeds per hill (4-6) and, after emergence, thin out all but the two most vigorous seedlings (Heiligman, pers. comm.). Indeed, if seedling vigour is correlated with plant vigour and yield, this may be a feasible method to save the cost of expensive hybrid seed. Such a correlation, however, is rather weak.

<table>
<thead>
<tr>
<th>H</th>
<th>Heterogeneous</th>
<th>landrace of self-fertilizing crop</th>
<th>population of cross-fertilizing crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>HETEROGENEITY</td>
<td>varietal hybrid</td>
<td>top cross</td>
<td></td>
</tr>
<tr>
<td>INTY</td>
<td>Homogeneous</td>
<td>multi-line</td>
<td>double cross</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>three-way cross</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td>pure line</td>
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<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Homozygous</td>
<td>Heterozygous</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.1** Relationship between heterogeneity, heterozygosity and cultivar type (adapted from Becker & Leon, 1989)

The constraints to saving hybrid seed on-farm, offer commercial seed producers a ready market since farmers have to buy seed for every crop. Many seed companies, therefore, concentrate on crops of which hybrids can be commercialised, e.g. the field crops maize, sorghum, pearl millet and sunflower, and vegetable crops like tomato, capsicum, eggplant, onion, cabbage, cucumber and melons.

Because of their uniformity, hybrids can be considered to be less adaptable than open-pollinated varieties. Their higher yield potential often is concomitant with a lower yield stability (especially under stress conditions: Chapter 6). For some characteristics though, such as disease resistance, hybrids may offer the additional advantage of combining different alleles in one plant. Hybrids, therefore, are considered to be more profitable for the more financially-secure farmer. When hybrids were introduced in Kenya, Allen (1966) designed his often-quoted ‘maize diamonds’ to illustrate the advantages of hybrids under conditions of good crop management and added fertiliser (Fig. 3.2). This figure also indicates that improving the general crop husbandry is much more effective than is the introduction of hybrids in an unimproved cultivation system. ‘Bad husbandry’ includes late planting, low plant population and poor weeding.

Hybrids, however, do not always need added fertiliser to out-yield open-pollinated varieties. Those selected from situations of low fertility might well out-perform local varieties. The diamond shows, however, that the extra (and recurrent) expenditure on hybrid seed is most effectively used in combination with a high basic yield level (i.e., good husbandry and high soil fertility).
Plate 3.2 A hybrid rice production trial, Sukamandi, Indonesia

Figure 3.2 Maize diamond (adapted from Allen, 1966).

Actual yields obtained (kg/ha) with four combinations of general crop husbandry, seed types, and added fertiliser. Added gross profit (KSh/a) compared with the most basic treatment, is given in parentheses.

Hybrid seed production is more complicated than is the production of composite or pure-line seed. The former requires good soil preparation and well-timed planting to obtain the best 'nick', i.e., the best synchronisation of pollination and receptiveness of the stigma. Also, emasculation has to be done with the utmost care to avoid selfing. Hybrid seed production should be done by professional seed companies who employ, as contract growers, only those farmers who can afford to invest sufficient care and money in the seed crop.

Avoiding selfing in hybrid seed production

Emasculation is the removal of potentially effective male flowers or anthers from the seed parent. If done at the appropriate time, it allows crossing to take place either naturally or by hand. Mechanical emasculation is used, for example, in the production of seed of hybrid tomatoes. Every flower bud of the seed parent is opened and the anthers removed before the pollen is shed; thereafter the stigma is pollinated by hand with the pollen of the pollinator line of the hybrid. This manual emasculation is done only with seeds of high-value vegetable crops (eggplant, tomato) and flowers (Impatiens). In plants with large flowers, or where the male and female flowers or inflorescences are clearly separated (coconut, maize) emasculation is much easier and large-scale hybrid seed production is possible at a reasonable cost.

In the case of maize, the tassels have to be removed as soon as they emerge. They can be pulled out vertically but
care has to be taken that the complete tassel is removed so that no male florets remain to shed pollen. Early pulling of the tassel may result in the removal of a number of the upper leaves, thereby reducing the yield of the seed parent. Special emphasis should be given to the removal of side shoots (de-suckering) before they produce tassels. Maize hybrid seed is produced normally by alternating two rows of the pollen parent with six rows of seed parent plants. Some additional pollen parent lines may be planted around the field as guard rows against alien pollen.

In coconut hybrid seed production, pollination is done by hand and the female flowers at the base of the inflorescence are bagged to avoid contamination by stray pollen.

For a number of years, emasculation by specific chemical compounds (gametocides) has been researched, especially for the production of hybrid wheat varieties. Due to poor pollen dispersal under suboptimal weather conditions, to date it has not been successful with wheat but it is used in rye seed production.

Plate 3.3 Mechanical emasculation for hybrid eggplant seed production (courtesy of Royal Sluis)

The use of male sterility obviates expensive mechanical or unreliable chemical emasculation by introducing a genetic (cell nuclear or cytoplasmic) inhibitor of anther or pollen development, or mechanisms whereby the release of functional pollen is inhibited (functional male sterility). It is used in hybrid breeding for crops such as sunflower, onion, capsicum and rice. A major difficulty is the production of the male-sterile inbred parent which, obviously, cannot be produced by selfing. A 'maintainer line' which, except for the male sterility gene(s), is genetically identical (isogenic) with the seed parent, is necessary. Crossing of the male-sterile seed parent with this maintainer line produces seed of the former. Development of this maintainer, which has to be as similar as possible to the male-sterile line, requires a lengthy breeding procedure. The use of male sterility has an additional problem when the crop is grown for its seeds (e.g. sunflower): the pollen parent of the hybrid has to have specific genes capable of restoring fertility in the final hybrid. Without such restorer genes the hybrid will produce no seed at all.

In the production of hybrid seed of insect-pollinated crops, pollination is generally not too difficult. Pollination of the male-sterile seed parent of a normally self-fertilizing crop could be a problem when the anthers are normally enclosed in glumes or other organs (cleistogamous), as is the case with rice and barley. Parent lines with protruding anthers are required in such cases.

Incompatibility is the genetically-controlled inability of gametes and egg nuclei to mate, even though both the pollen and egg cells are basically functional. This usually occurs as the inability of pollen to fertilize the egg cell of the same flower (self-incompatibility) but it can happen with any combination of parents (cross-incompatibility). Hybrid seed production is possible without emasculation if a self-incompatible seed parent is cross-compatible with the prospective pollen parent. Though not without problems, the production of the self-incompatible line is much more easily achieved compared with the production of the above-illustrated male-sterile parent line. Incompatibility is widely used in cabbage breeding.

Seed production aspects of plant breeding
In some cases seed production characteristics are important breeding objectives. For crops whose seed is not the harvested product, flowering and seed-setting normally reduce yield (e.g. lettuce and grasses) or make the whole crop inedible (onion, carrot and cabbage). Breeders will, in such cases, select against flowering habits. The seed producers' requirements, however, must also be taken into account. A grass variety that produces a lot of biomass without flowering, is useless. A non-flowering onion variety may also not be considered for release.

Even where the immature fruits or seeds are eaten, (e.g. French bean, yardlong bean and pea) the breeder will select for non-shattering types: though this characteristic is
not required by the farmer, it is vital for the seed producer. In the case of potato, clear visibility of virus infection is necessary in order to rogue diseased plants in seed crops. Varieties in which symptoms of virus infection are not easily visible, should not be commercialised.

Seed production requirements may be decisive selection criteria in hybrid development. In India, production of a number of sorghum hybrids had to be discontinued and release withdrawn for seed production reasons (Chopra, 1982). In the hybrid ‘CSH-1’, the pollen parent was three feet shorter than the seed parent, thus reducing effective pollination in the seed production field. That the styles of the seed parents of ‘CSH-3’ and ‘CSH-4’ did not protrude is not important in commercial sorghum production but is disastrous for a seed parent of a hybrid. Also, because the neck of the two parents of ‘CSH-5’ differed by as much as 15 to 20 days, staggered planting was necessary; an added strain on seed production management and an extra cost factor. Furthermore, the seed parent of this hybrid had very large heads, causing variation in seed size and germination capacity.

Variety release
In an institutional system of seed production, variety release procedures often are applied by the national authorities. A variety release committee prepares minimum standards for testing varieties for value for cultivation and use (VCU) and, often, also for DUS. These two tests serve rather different purposes:

- **DUS tests** establish whether a proposed new variety can indeed be considered both 'new' and 'a variety'. They involve the description (mainly morphological) of the proposed variety and comparison with all the described varieties. In addition, phenotypic uniformity is assessed during the first grow-out trial. In a second growing season, the description and the comparison are checked and seasonal differences (due to either lack of stability or a clear reaction to different seasons) may be noted. The tests are done under optimal cultivation practices, often in one or a few locations only. These tests determine whether the candidate variety is distinct from the existing ones (so that, for example, field inspectors will be able to identify the variety). They also determine whether the variety is sufficiently uniform so that off-types can be identified and stability can be assured, i.e. that the variety can be multiplied without changes in its characterising properties (for example, due to segregation and natural selection). In addition, DUS tests are important to assess the eligibility of a variety for plant breeder's rights (Chapter 5).

- **VCU tests**, often called ‘performance tests’ or ‘variety tests’, assess the agronomic performance of the variety and the value of the product for consumption or other purposes. A VCU testing system generally implies grow-out tests (on station, in coordinated multi-localional trials and, sometimes, in on-farm trials). Often, a minimum of three seasons of multi-localional trials is applied. Very strict systems of variety testing can be found (e.g. India) that are comparable to the procedures for field crops in Europe. Other countries allow new varieties onto the market more easily: this applies to non-staple crops, like vegetables, in particular. The VCU tests are either fully controlled by the breeder himself, or an independent body is made responsible for the organisation and execution of the trials. Different levels of management may be applied for each variety at each variety-trial location. Often, though, good management with a rather high input level is used in order to get the clearest differences in yield and the smallest coefficient of variance (= standard deviation divided by the trial mean). This, however, results in a bias towards selection for the better-off farmer who also uses these input levels. The variety trial centres should be located in all major crop production areas of the country. On-farm trials often are not required (and not considered) by the variety release committee, but the results may serve as additional support for the release. Moreover, they can have an important demonstrative value for prospective users of the variety.

In most countries, a new variety is released only if the trials show a significant yield advantage compared with the standard varieties or when certain non-yield attributes are considered advantageous. An example of the latter is the soya bean variety 'Nam. 1' in Uganda. It was released because of its resistance to bacterial pustule and its reduced shattering in the field. The trials were always harvested early and with much care to avoid shattering. Yield figures were not spectacularly higher than for the existing varieties but the other two characteristics were considered important enough to warrant release.

Release can be full, temporary or restricted. Full release means that the variety is considered useful throughout the country and for all growers of the crop. Temporary release means that the committee still has some doubts about the performance but that the variety can be commercialised pending further trial results. Restricted release means that the variety is released for use in certain (agro-ecological) areas or for certain types of farmers. This last is merely a recommendation.

Varieties that do not pass VCU tests, are not normally allowed in the seed production system. This means that only very few varieties can be commercialised in a particular country. In many developing countries this VCU system functions for the major (food) crops only.

The above clearly shows that 'An improved variety is the product of very considerable work and effort. Very many selections will not be suitable to go forward to large-scale seed production. Those varieties which qualify must, therefore, be treated with respect and deserve a well-designed and executed multiplication and distribution system' (Kelly, 1989).

Variety maintenance
Once a variety is released there has to be a steady supply of Breeder Seed to the seed multiplication system. The breeder is normally charged with this task. While producing these
relatively small quantities of basic material, the maintenance breeder has to make sure that the variety remains true to its original description. Changes in the variety may be due to (natural) selection in an open-pollinated variety, genetic drift, segregation, mutation, introgression or to mechanical admixture. Varietal maintenance thus is necessary throughout the 'economic life' of the variety, i.e. as long as seed of the variety is produced.

Maintenance involves a very strict selection in the variety. Minor differences have to be identified and removed. This can be realized through positive or negative mass selection, through line selection in self-fertilizers or family selection (half-sib, full-sib) in cross-fertilizers. The International Centre for Maize and Wheat Improvement (CIMMYT) recommends, for example, a half-sib family selection method with at least 500 families for the maintenance of open-pollinated maize varieties, using detasseled seed parents, planted in family rows and a mixture of pollinators from the same 500 families (CIMMYT, 1984). Stricter methods of variety maintenance of maize include sib selection with remnant seed procedure and family yield tests. The amount of energy invested in variety maintenance is related to the level of variation in a variety and the requirements of the seed market (including legal uniformity standards - Chapter 5). The maize examples above illustrate that variety maintenance can be very laborious, involving the same techniques and administration as a plant breeding programme.

When insufficient attention is given to maintenance, a variety may lose the particular characteristics for which the variety was bred. In Uganda, the maize composite 'KWCA' was maintained for 15 years by selecting large and healthy cobs after harvest. Seed from these cobs was then sown for the next generation maintenance and for Breeder Seed production. This procedure resulted in an excessively tall crop (4 m) causing lodging, a two weeks extension of the maturity period and a single large cob rather than two smaller ones per plant. The variety, therefore, was less suited to areas with a shorter growing season. Also, lodging due to excessive height was rampant. The method of variety maintenance must have been responsible for these changes: selection on cob characteristics implies selection for fewer but larger cobs per plant, competitive plants (tall) and late maturity (higher plant yield). The risk of changes is greater in cross-fertilizing than in self-fertilizing crops.

Improved storage conditions can reduce, significantly, the cost of variety maintenance, especially for crops with a high multiplication factor. With such crops Breeder Seed, sufficient for a number of years, can be produced in a single season (Fig. 3.3). An extreme example is tomato varieties in Europe where sufficient quantities of Breeder Seed are produced upon release and stored throughout the economic life of the hybrid (often only a few years). Before every seed-production season, the required amount is taken out of the store. This means that variety maintenance is limited to the purification activities at the end of the breeding programme.

![Figure 3.3 Flow diagram of maintenance strategy and subsequent three-stage production scheme](Andrews and Harinarayana, 1994)
Seed production agronomy

Agronomic practices for seed production generally follow the standard farming methods for the particular crop: proper land preparation; optimum plant spacing; soil fertility management; and good weed, disease and pest control. There are some general differences, however, between cultivation practices for grain and seed production and very specific practices are required for certain crops (biennials, hybrids, woody plants and pasture crops). The main differences between grain production and seed production concern the quality requirements of the latter. As discussed in Chapter 1, seed quality characteristics relate to genetic, physical, physiological and sanitary quality.

![Plate 3.5 Rogueing a rice seed production field in Sri Lanka (courtesy CPRO-DLO Wageningen)](image)

**Genetic quality** of seed is guaranteed through application of the following measures:

- Sowing of the right class of seed: generally one class higher than the seed to be produced (see below).
- Minimising contamination with foreign pollen through adequate isolation distances between the seed crop and other crops of the same species and through removal of volunteer plants in and around the seed production fields. In some crops, certain common weeds are able to genetically contaminate a seed crop (e.g. *Sorghum verticilliflorum* in *Sorghum bicolor* seed crops in East Africa). Such weeds have to be removed with great care.
- Avoiding mechanical admixture. Blending can occur during planting, but occurs especially during harvesting and post-harvest operations. Preventative measures include: isolation distance, especially in crops that are creepers (e.g. sweet potato and vegetable cowpea); the use of properly cleaned harvesting bags; and cleaning of harvesting and threshing equipment between the different seed lots and varieties.
- Rogueing of off-type plants during the critical stages of crop development is necessary to improve the genetic purity of the seed crop, i.e. normally, during early flowering and before harvesting.
- Eliminating volunteer plants in the field through good crop rotation. In cropping systems where the same crop is planted every season (e.g. irrigated rice) two rather opposite measures may be recommended: either use as distinct varieties as possible in rotation so that volunteers can easily be recognised; or plant the same variety every season so that volunteers cannot do much harm to the seed quality.

If these measures are not taken, the genetic composition of the variety will change due to introgression, mutation and mechanical mixing and the variety 'runs out' (of its original description).

**Physical quality** of seed relates to admixtures in the seed lot, e.g. stones, straw, broken seeds, other inert matter and seeds of other crops and weeds. The first three types usually get mixed with the seed during harvesting and drying operations. Seed production agronomy, however, can influence significantly the content of weed seeds in a seed lot. Insufficient weeding during the later stages of crop production, generally, will increase the number of weed seeds picked by a combine harvester (e.g. wild grasses in millets). In most cases, these can be removed by seed cleaning. The classification 'noxious weeds' is used to designate weeds that can seriously affect the crop. *Rotthoellia exaltata* is a typical example. When the seeds of noxious weeds cannot be cleaned easily out of a seed lot because of similar seed size, shape and density, agronomic practices have to concentrate on removing those weeds from the seed fields before harvesting.

**Physiological quality** of seed can be improved through the following measures:

- Proper timing of planting to secure sufficient moisture during flowering and to allow harvesting operations to take place in a period of the year with a high probability of dry weather.
- Careful use of nitrogen fertiliser to avoid excessive vegetative development of the crop and to improve the storage potential of the seed. Potash and potassium fertilisers generally have a positive effect on seed quality.
- Timely and careful harvesting operations. Physiological seed quality is, in principle, highest at physiological maturity, i.e. the moment that its development is complete and reduction of seed moisture content starts. From a seed physiology point of view, harvesting should be done as soon as possible after physiological maturity but handling of the immature crop and swollen seed, often, is not possible. On the other hand, harvesting when the seed is too dry can result in breakages. The optimal time for lifting a groundnut seed crop, for example, can be very difficult to determine: early harvesting results in shrivelled seeds after drying and delayed harvesting results in most pods remaining in the soil. In some crops with large
Inflorescences, such as some millets, onion, carrot, and pasture grasses, the moment of seed maturity is difficult to judge. Within a single inflorescence, the individual seeds may differ markedly in maturity at any one time. In general, harvesting may be improved by assuring uniform crop growth by proper seed-bed preparation and uniform cultural practices such as weeding and fertilising.

- Good weed control and optimum plant density should guarantee well-filled seeds. Plant density is particularly important in seed production agronomy. Often, a relatively low population density is advisable in seed crops, especially where wider row spacing can reduce the spread of diseases, e.g., diseases that are spread by rain splashes, or viruses that are spread mechanically. An increased plant population density is advocated for some vegetables where, normally, immature fruits are picked during the growing season (e.g., sweet pepper, eggplant). For fruits that are left on the plant until full maturity, vegetative plant growth may be considerably reduced and a closer spacing applied. In some cases, an increased plant population density reduces disease incidence (e.g., Rosette in groundnut).

- Insects that can seriously damage the seed quality have to be controlled. Examples are pod-sucking pests in soya bean and virus-transmitting aphids in many crops. Even when they are not seed transmitted, plant diseases can affect physiological seed quality and should be controlled.

Sanitary quality of seed is extremely important in most seed-production operations and specific rules have to be developed by the seed-quality control institutions in every country. Many diseases are crop and region specific. Proper knowledge of the reproduction and spread of the diseases is essential. Seed-transmitted disease control follows the same procedures as are employed in food crop management, but should be affected with extra care. They include:

- The use of healthy seed.
- Crop rotation, to avoid inoculum accumulation in the soil (Bacterial Wilt in tomato, Common Bacterial Blight in beans, club root in cabbage) or in the stubble of the previous crop (Northern Leaf Blight in maize).
- Control of alternative hosts in the weed population in and around the field.
- Reducing the spread of diseases through crop isolation or appropriate planning (no planting of seed crops in areas where certain diseases are known to be rampant, e.g., Bacterial Wilt of potato in many tropical regions below altitudes of 1500-2000 m). In some cases, certain regions are designated for seed production of a particular crop only and strict phytosanitary methods are applied (no seed in, only seed out). In seed potato production a 'flush out system' can be used whereby the highest generations (e.g., Breeder Seed) are grown at the highest altitudes. Increased row spacing can reduce the spread of diseases especially in early crop development.
- Timely chemical control against the disease itself or against its insect vectors (e.g., aphids for many viruses).
- For some crops, it is possible to avoid diseases, e.g., early harvesting of seed potatoes before aphid-borne diseases can develop. In general, planting early in the season reduces disease incidence.
- Roguing of diseased plants is sometimes effective and necessary, as in cases of low incidence of Common Smut in maize. However, for diseases that are not seed transmitted (such as Maize Streak Virus) roguing of infected plants seldom is economically feasible.

It may also be beneficial to plant in rows those crops which, normally, are planted by broadcasting the seed. Weed and disease control and field inspection may be facilitated by so doing. Often, multiple cropping techniques are not allowed, although the rationale behind such measures is not always clear.

Plate 3.6 Transmission of a fungal disease through seed: Anthracnose in common bean (courtesy of CPRO-DLO Wageningen)

Despite all the measures mentioned above, seed production of many major crops is merely crop production with extra care and adherence to some additional rules. Exceptions are biennials, hybrids, tree and pasture species. Also, in crops where the harvestable product is not the seed itself, a special methodology has to be used. For example, though not a common practice, large-scale seed production of cassava is done best using a very narrow spacing thereby forcing excessive stem growth and reducing root production (large-scale certified cassava seed production, however, is not practised often).

Biennials

Biennial vegetables are an important group of crops that require special techniques for seed production. They flower only after an extended vegetative period and often require specific types of flower induction: cold treatment...
(vernalisation) followed by long days. Examples are onion (and relatives) carrot, lettuce, radish, and cabbages. Often, day-length sensitivity can be overcome by breeding day-neutral varieties. Seed production details of these and other vegetable crops have been described by George (1985) but some general remarks are made here.

Seed production generally starts with normal crop production procedures, with the added consideration of a carefully chosen site. These crops are exotic to most tropical regions and, often, seed production can be realised only at higher altitudes or latitudes (e.g. onion seed production near Poona, India). In exceptional cases some individuals of these crops may flower under tropical lowland conditions but rigorous selection for these early bolting types usually reduces the agronomic performance of the subsequent crop; harvesting of the cabbages or onions produced from these seeds has to be advanced to avoid bolting and, consequently, crop production is reduced. In some tropical areas local varieties of these crops have been selected because they behave as annuals: farmers in the highlands of Indonesia (above 700 m) grow their own carrot, cabbages and cauliflower seed, and onion seed is produced in West Africa. Many highland areas in the tropics (above 1500 m) are not ideal for seed production of these crops because they are too cool for rapid and healthy vegetative growth and, most of the time, are too wet due to low hovering clouds. Onion seed, especially, can be affected by these conditions. Alternatively, the bulbs can be produced under optimal conditions (dry lowland) cold-treated in a cold room such as a fish plant (Sri Lanka) or a municipal ice plant (Uganda) and replanted in a dry and warm area. Even transporting the bulbs to a higher elevation for a period of vernalisation and then back to the lowlands for seed production has been done but it is rather inefficient and economically less favourable than seed importation. Large-scale radish seed production in Sri Lanka is very successful under highland conditions.

Hybrids

The various kinds of hybrids have been outlined above. From the point of view of seed production agronomy, it is important to know whether male sterility or self-incompatibility applies, or whether mechanical emasculation has to be done. The quantities of pollen produced and the timing and duration of pollen shedding in relation to the receptive period of the female parent are also relevant to the planning of seed production. In most developing countries maize detasselling is done manually and requires considerable additional labour and management input to check on these important operations. Mechanised detasselling is done in large-scale production fields, for example, in the USA.

Agronomic measures to improve hybrid seed production of sunflower may include the introduction of beehives in the field to assure sufficient pollination and to prevent bees from distant colonies entering the field and possibly introducing foreign pollen.

Hybrid seed production of solanaceous vegetables like tomato, sweet pepper and eggplant requires manual emasculation thus greatly increasing the labour and management requirements for seed production relative to vegetable production. This situation led Western seed companies to transfer most of their production of these hybrid seed crops to Southeast Asia and other areas where low labour costs are combined with good infrastructure and management capacity.

Tree and pasture species

Details of tree multiplication and pasture seed production go beyond the scope of this book. In brief though, tree species include most fruit trees, plantation crops and forest trees. Propagation material often is budwood taken from certified mother plants or seed collected from trees of certified origin. Aspects of various methods of vegetative propagation have been described by Hartmann and Kester (1968) and information on tree seed production has been compiled by Edwards (1987), Portlock (1988), Turnbull (1990) and Gordon et al. (1991).

Seed production of forage legumes and grasses requires special techniques, especially with regard to weed control and harvesting. The best sources of information on this subject are the Queensland Department of Primary Industries in Australia (QDPI, 1988), FAO (Humphreys, 1974; Skerman et al., 1988; Skerman & Riveros, 1990) and Boonman, (1993).

Seed classes and production planning

Seed classes

To assure the genetic identity and purity of each seed lot, a strict generation system is used in every certification scheme. Without strict control, seed will deteriorate after each generation due to cross fertilization, mechanical admixture, mutations and/or natural selection. This is the reason why the original breeder of a variety is normally charged with variety maintenance and Breeder Seed production. The Breeder Seed has to be the purest form of the variety at a particular time. Because of the small quantities involved (from a few grams to a few kilograms, depending on the crop), inspection can be done on minute morphological differences between individual plants. Every Certified Seed lot is derived from a particular lot of Breeder Seed via a known number of generations which are named according to one of two widely used systems of nomenclature: that of the Organisation for Economic Cooperation and Development (OECD) system (originated in Europe) or the Association of Official Seed Certifying Agencies (AOSCA) system of the USA. Table 3.2 compares the two.

Even within OECD countries different designations are used for different crops, e.g. Super Elite, Elite, and Certified for potato and flax, equivalent to the respective
Table 3.2 Seed classes

<table>
<thead>
<tr>
<th>Generation</th>
<th>OECD</th>
<th>AOSCA</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Breeder</td>
<td>Breeder</td>
<td>Breeder responsible for producing this category from nucleus material.</td>
</tr>
<tr>
<td>2</td>
<td>Pre-Basic</td>
<td>(no direct equivalent)</td>
<td>In AOSCA system, a second generation may be a multiple of BS or an early FS class. The breeder is responsible.</td>
</tr>
<tr>
<td>3</td>
<td>Basic</td>
<td>Foundation</td>
<td>Produced by specialised seed growers under breeder's supervision.</td>
</tr>
<tr>
<td>4</td>
<td>Certified-1</td>
<td>Registered</td>
<td>Produced by seed organisations on a large scale and sold for crop production.</td>
</tr>
<tr>
<td>5</td>
<td>Certified-2</td>
<td>Certified</td>
<td>Produced by seed organisations on a large scale and sold for crop production.</td>
</tr>
</tbody>
</table>

Source: based on Cromwell et al., 1992

Pre-Basic, Basic and Certified Seed classes. Some individual countries use yet other names, e.g. Stock and Extension Seed for Registered and Certified Seed respectively (Indonesia) and Approved Seed for Registered Seed (Pakistan). In addition to the above, many countries have a 'Commercial', 'Labellod', or 'Good for Sowing' seed class (or various other names), to designate seed that is produced outside the certification system but for which laboratory tests show at least minimum levels of germination and purity. The varietal identity of the seed of these classes cannot be guaranteed. Such seed can be sold in emergency situations where Certified Seed is in short supply.

Seed production planning
Planning a seed production programme requires a business approach. It should start with an assessment of market demand and be followed by an analysis of expected returns and risk factors before final allocation of resources (seed, land, manpower and funds).

Because of the generation system, seed production planning becomes rather complicated. Changes in demand cannot be met immediately by appropriate changes in production because Certified Seed production depends on the availability of Registered Seed. Excessive production of Registered Seed in a declining market for Certified Seed of the particular variety can amount to substantial wasted expense. Also, holding stocks of lower generation seed (Certified-2) to meet any sudden increased demand is often too costly although, in Zimbabwe, an amount equal to 20% of the expected demand for maize seed is kept as a security stock.

In practice, the Breeder- or Foundation Seed classes appear to be the bottleneck in the supply systems, especially where the lower generations are multiplied by a specialised seed organisation and the highest by a government research institute that cannot easily be integrated into a commercialised production plan. The demand for seed of a particular variety can, for example, collapse as a result of a breakdown of the resistance mechanism due to the development of new strains of the pathogen. On the other hand, a sudden increase in demand for a variety may occur when the resistance of a competing variety has been broken. Demand for seed can also be expected to increase when prices for the commodity rise. Market forecasting, therefore, is extremely important.

Biological factors of the crop are also important in production planning. A suitable tool for quick assessment of the required quantities of successive seed classes is the multiplication factor (mf) of the crop. It is the amount of clean seed produced, divided by the amount of seed sown per unit area. A typical example of the use of this in planning is presented in Table 3.3. It presents a situation in which groundnut seed is produced once per year. For this example, mf = 10, i.e. 90 kg of seed is planted to produce 900 kg of cleaned Certified Seed per hectare (in many cases the mf for groundnut is even lower). In calculating the mf one should include total yield, processing losses, losses due to rejection of part of the crops by the quality control system and, in some cases, theft.

Table 3.3 illustrates advanced planning for the production of seed of a newly introduced variety for which a steadily increasing market is foreseen up to a ceiling of 1000 tonnes of Certified Seed to be reached in 1999. It must be borne in mind that this estimate is subject to a certain level of speculation (or wishful thinking). Breeder Seed for the 1999 planting season has to be planted in 1995, i.e. when the first proper sales (600 t) are expected. At the same time, 900 kg of Foundation Seed has to be planted to produce 9 t and this requires 10 ha of relatively expensive land on a Foundation Seed farm.

This example also shows the vulnerability of the system. A bad year in 1995, with harvests of 600 kg instead of 900 kg of clean seed per hectare, would not produce 9 t of Foundation Seed, but only 6 t. Three years
Table 3.3  Seed production planning for groundnut

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified Seed (t)</td>
<td>250</td>
<td>600</td>
<td>750</td>
<td>900</td>
<td>1000</td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registered Seed (t)</td>
<td>25</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation Seed (t)</td>
<td>2.5</td>
<td>6</td>
<td>7.5</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breeder Seed (kg)</td>
<td>600</td>
<td>750</td>
<td>900</td>
<td>1000</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

later the supply of Certified Seed would be 600 t while the expected demand would be 900 t. This is a serious loss of business. The following year (1999) only 666 t of Certified Seed would be available due to the same troublesome event four years earlier. It is necessary, therefore, to build some security into the original planning. One safeguard is already built in if one assumes that the Certified Seed producers (often, contract growers) have a somewhat lower standard of agronomic practices than that of the Foundation Seed farm. The multiplication factor in the higher generations will thus be somewhat higher. The chances of a crop being rejected by field inspectors may also be higher for the contract growers. Therefore, by using the multiplication factor for Certified Seed for all seed classes, a slight over-production of the higher seed classes will result. In effect, the necessary buffer stocks are built up. Sizable security stocks of Certified Seed are too expensive to maintain but a security of one year’s requirement for Breeder Seed is a minimum for a serious seed producer. Storage of one year’s demand for Foundation Seed may be feasible in some situations. The longevity of the seed and the facilities for long-term storage also affect the feasibility of high-generation seed storage.

Other methods to buffer changes in demand include:

- using contract growers introduces an important flexibility in land allocation for seed production; and
- using price differentials and advertising to manipulate seed in stock.

Seed production planning can be simplified by using spreadsheet computer programs. In practice, rarely is this done in the tropics because the magnitude of the uncertainties regarding inputs (especially market forecasts) generally reduces the practical value of precise calculations. Such programs, however, are especially important for the more complex planning for seed crops of biennials and for hybrids (because the production of seed parents and pollen parents has to be matched throughout the successive generations).

Economists and project planners use such spreadsheet programs extensively to present targets and project returns on investments. It is important that such figures are continually updated during project execution whenever new information about the actual harvests, stocks and markets becomes available.

Table 3.3 also shows that the introduction of a new groundnut variety requires a long time. Assuming that the breeder has 500 kg of the variety at the time of release (1991), 250 kg may be used to produce Foundation Seed. Seventy kilograms will be needed for Breeder Seed production (to satisfy the expected demand of 600 kg in 1992), leaving only 180 kg for further research, demonstrations and security. Limited quantities of the new variety will be on the market only in 1995.

A well-publicised release in 1991 may well mean that by the time the farmers can buy its Certified Seed in sufficient quantities they have become impatient and are reluctant to buy. By then, a newer improved variety may have been bred and advertised. There will be some pressure, therefore, on the breeder and the seed producer to supply certain quantities of seed early. This, in turn, will further delay the production of large quantities of Certified Seed. The problem may be reduced both by producing sizeable quantities of (at least) Foundation Seed prior to release and by delaying advertising. Part of this seed can be downgraded to produce some Certified Seed, while the balance is used to produce the Registered Seed. Pre-release production, however, is risky for the seed producer, who
Table 3.4  Multiplication factors used by the Uganda Seed Project for seed production planning in 1991, and the quantities of Certified Seed produced in that year

<table>
<thead>
<tr>
<th>Crop</th>
<th>Multiplication factor</th>
<th>Approximate annual production of Certified Seed (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (OP)</td>
<td>100</td>
<td>800</td>
</tr>
<tr>
<td>Sorghum</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>Sunflower</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>Soya bean</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Common bean</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Groundnut</td>
<td>8</td>
<td>150</td>
</tr>
</tbody>
</table>

Source: ACE, 1992 and authors’ observations

may not be allowed to sell the seed should variety release be delayed for whatever reason.

It is clear from Table 3.4 that groundnut is a rather extreme example because its multiplication factor is low compared with most other crops. It does, however, illustrate very well the various aspects of seed production planning. Note that the multiplication factors are rather conservative. This reduces disturbances in the planning by allowing for various problems during the cultivation of the different generations: problems such as poor weather conditions and the use of part of the contractor-grown seed for food. The figures also show that the Registered Seed class is not always required for crops like maize and sorghum that have high multiplication factors, or for crops (e.g. sunflower) with a low production target for Certified Seed.

Timely shelling is determined by the moisture content which, in turn, plays an important role in the future germination capacity of the seed lot. Over-dried seeds are more likely to crack when shelled, while shelling at high moisture levels may tear the seed coat.

Fumigation
Some crops are infested by storage insects in the field, others are infested during drying or initial storage. If not controlled, these insects can multiply very rapidly leading to complete loss of the seed crop. On receipt from the farmer, the seeds are fumigated to ensure that any insects, their larvae and/or eggs are destroyed before they can invade the seed stores and the processing plant. Any rodents hiding in the bags are also killed by this treatment.

Drying
Seed loses its viability during storage. The rate at which this occurs depends, to a large extent, on the seed moisture content (see Table 3.5). High moisture levels increase the life processes in the seed and, therefore, result in rapid ageing and loss of viability. Harvesting of the seed at the optimum stage of seed development, natural or artificial drying and dry storage conditions are important preconditions for good quality seed supply.

Table 3.5  Effects of the seed moisture level on cereal seeds

<table>
<thead>
<tr>
<th>Seed moisture level</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>above 40-60 %</td>
<td>germination occurs</td>
</tr>
<tr>
<td>above 18-20 %</td>
<td>heating may occur</td>
</tr>
<tr>
<td>above 12-14 %</td>
<td>mould growth</td>
</tr>
<tr>
<td>above 10-12 %</td>
<td>sealed storage unsafe</td>
</tr>
<tr>
<td>above 8-9 %</td>
<td>insects active</td>
</tr>
</tbody>
</table>
Seeds have an internal moisture content which is in equilibrium with the relative humidity of the surrounding air. Each seed type has its own moisture equilibrium levels (see Table 3.6) and even different varieties may have different hygroscopic properties.

Drying of seed to the equilibrium moisture content should be done soon after harvesting to avoid fungal growth. It should be done with care to avoid physiological damage. Seed drying starts on the plant and can be accelerated by cutting the plant and allowing it to weather in the field. Sunflower heads, for example, can be cut and placed on the cut stalks for sun drying. In dry areas sun-drying can be dangerous. Nautiyal and Zala (1991) reported significant yield losses in groundnut when the plants were wind-rowed in the field after lifting. Temperatures can increase up to 44° C causing physiological damage. Piling the plants such that the nuts were not exposed to direct sunlight proved to be much better. In the wetter parts of East Africa, mould growth can occur even in windrows and careful upside-down heaping of the plants proved the best way to secure an acceptable level of drying. Seed drying is carried out at various levels of sophistication on floors, in trays, in carts and in cribs, or with the use of large fans.

Cribs can be very effective in drying particular seeds, especially in areas with a high risk of rainfall after harvesting. The width of the crib relates to the relative humidity during drying (maximum 2 m wide in dry areas; 1 m in moist areas). Artificial dryers which use heated air include batch-, bag- and box-dryers and various types of continuous-flow dryers. Temperature control is vital. The more moist the seed the more sensitive it is to physiological damage due to over-heating. Damage may occur as low as 40° C. In warm humid areas there may be a very limited temperature range at which drying can be done effectively and safely.

There is no point in drying seed beyond the equilibrium level if it is not going to be packed in sealed containers; the seed moisture will rise again to the level of humidity in the air.

The effects of seed moisture content on insect infestation are discussed further on in this chapter.

### Seed cleaning

Seed cleaning is done by sorting the raw seed according to its shape, size, width, length, density, colour, texture, etc. All these characteristics are used to identify the good seeds of a specific crop and to separate them from different kinds of inert matter such as stones and chaff, unwanted weed seeds, other crop seeds, broken and insect damaged seeds or, sometimes, even seeds of other varieties of the same crop.

Three types of machines are used most frequently to derive a uniform seed lot: the air-screen cleaner, the operated cylinder and the gravity table. These and other machines are discussed below.

---

**Table 3.6** Approximate seed moisture levels (wet basis) in equilibrium with various levels of ambient relative humidity

<table>
<thead>
<tr>
<th>Crop</th>
<th>45%</th>
<th>60%</th>
<th>75%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed moisture levels (% wb)</td>
<td>Relative humidity (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>10.0</td>
<td>12.1</td>
<td>14.4</td>
<td>19.5</td>
</tr>
<tr>
<td>Maize</td>
<td>10.4</td>
<td>12.9</td>
<td>14.7</td>
<td>18.9</td>
</tr>
<tr>
<td>Rice</td>
<td>10.7</td>
<td>12.8</td>
<td>14.6</td>
<td>18.4</td>
</tr>
<tr>
<td>Sorghum</td>
<td>10.5</td>
<td>12.0</td>
<td>14.6</td>
<td>18.8</td>
</tr>
<tr>
<td>Wheat (durum)</td>
<td>10.0</td>
<td>11.5</td>
<td>14.1</td>
<td>19.3</td>
</tr>
<tr>
<td>Groundnut*</td>
<td>5.5</td>
<td>7.0</td>
<td>19.5</td>
<td>17.2</td>
</tr>
<tr>
<td>Soya Bean*</td>
<td>7.5</td>
<td>9.3</td>
<td>13.1</td>
<td>18.8</td>
</tr>
<tr>
<td>Pea*</td>
<td>11.1</td>
<td>13.5</td>
<td>15.8</td>
<td>22.0</td>
</tr>
<tr>
<td>Bean</td>
<td>9.4</td>
<td>12.0</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>6.4</td>
<td>7.6</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Cucumber</td>
<td>7.1</td>
<td>8.4</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>7.1</td>
<td>8.4</td>
<td>11.1</td>
<td></td>
</tr>
<tr>
<td>Egg plant</td>
<td>8.0</td>
<td>9.8</td>
<td>11.9</td>
<td></td>
</tr>
<tr>
<td>Okra</td>
<td>10.0</td>
<td>11.2</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>9.5</td>
<td>11.2</td>
<td>13.4</td>
<td></td>
</tr>
</tbody>
</table>

* Some interpolation and extrapolation has been done to arrive at the 45% and 75% figures.

Source: Justice & Bass (1979)
Seed cleaners

Separation in air-screen cleaners is done on size, shape and density. The air-screen cleaner is the basic unit for general purpose cleaning of a wide range of seeds. It combines screens for size and shape separation with fans which separate on density characteristics. To avoid clogging of the top screen, a fan blows or sucks the chaff and other light trash away before the seed reaches the screens. A horizontal stack of two to four screens is used. The screens vibrate and oscillate such that the seeds are bounced over them to present all seed surfaces to the apertures of the screens. Bouncing may cause internal damage (e.g. soya bean) or damage to the seed coat (e.g. groundnut) and should be minimised.

In any seed-processing plant, round-, triangular-, and slotted-holed screens should be at hand. Different sized square or rectangular wire meshes can be used. When the seeds drop through the lowest screen they are subjected to a strong up-thrusting air current to remove any light-weight seed, possibly immature or insect damaged.

Because every seed lot is different, the seed-cleaning process normally starts with hand-sieving of samples with a selection of screens to choose the optimal combination. A first run with the air screen cleaner is used to set the fan speeds and the inclination of the screens.

Separation in indented cylinders is based on seed length and size.

The indented cylinder comprises one or more inclined, revolving cylinders which are indented with round depressions on the inside surface. A trough inside the cylinder collects seed that falls out of the pockets when these travel beyond the vertical position. Long seeds are not caught in these pockets and travel through the cylinder to the lower discharge. Unwanted long seeds or yet-owned cereal seed can thus be separated and discarded. On the other hand, round and broken seeds can be cleaned out of a long-seeded crop of kidney beans, for example, by using the lower cylinder discharge as the good seed outlet.

A set of indented cylinders can also be used to grade an otherwise pure seed lot according to seed size and shape (large flats to small rounds in maize). These characteristics influence uniformity in seedling vigour and thus synchronisation of germination, and are important considerations in the use of mechanical planters.

Indented cylinders can be adjusted by choosing the mantle with the desired indent size, by setting the inclination and the speed of the cylinder and by positioning the trough.

Gravity tables separate seeds and inert matter on specific gravity and, to some extent, size. The most commonly used is the triangular deck table.

A gravity table consists of a porous deck which can be tilted both lengthways and sideways. Outlets are provided on the side opposite the feeding hopper. A fan blows or sucks air through the oscillating deck and the combined actions cause the heavier materials to move to the higher corner, whereas the air lifts the light seeds from the deck and helps them to move to the outlet at the lower end. The different fractions collected, therefore, have very different compositions: the highest outlet carries off stones and some over-sized seeds; the lowest removes chaff and immature or insect-damaged seeds. Some of the higher-central outlets contain the best seeds; the contents of the lower central ones often are re-processed.

This type of seed cleaner can increase the viability and vigour percentages of an already-processed seed lot, and can thus be of tremendous value. Setting a gravity table requires a lot of skill and experience, however, because of the numerous combinations of deck oscillations, feed and fan speeds and deck materials and inclinations (Fig. 3.4).

![Figure 3.4 Gravity Table Adjustment Check Chart](Hamond et al., 1963)

**Key:**
1. Start the separation and wait for the material to define a constant pattern of distribution
2. Compare each pattern of material distribution with Fig. 1 for ideal or optimum adjustments
3. Correct errors of adjustment in the following order:
   i. Air adjustment Figs 2A or 2B
   ii. Econetric speed Figs 3A or 3B
   iii. End raised slopes Figs 4A or 4B
   iv. Side raised slope Figs 5A or 5B

**Other types of seed cleaners**
- Colour sorter: an electrical machine that can be used, for example, to separate varietal mixtures, disease-stained bean seed and groundnuts with damaged seed coats.
- Spiral separator: a machine that exploits differences in seed density and roundness (in soya bean, for example).
Cylindrical screen cleaner: is comparable with air screen cleaners but has rotating cylindrical drums instead of flat screens.

Pocket disc cleaner: is similar to an indented cylinder.

Needle separator: a cylinder with fine needles which can pick up insect-infested seeds (especially in legumes) and drop them in a trough, similar to the one in the indented cylinder.

Magnetic separator: a machine used to separate rough textured seeds from smooth ones by using fine iron dust and magnets.

Velvet roll mill: a machine to separate dodder (Cuscuta sp.) from pasture legume seeds.

Electrostatic separator: a machine which exploits differences in seed coat charging abilities.

Inclined belt separator: a machine which separates on surface texture and seed shape.

Picking belt: despite the above very advanced seed cleaners, hand-picking is often necessary, e.g. for diseased seeds. A flat conveyor belt can increase the efficiency of sorting by hand.

Other seed cleaning machines, and modifications of those above, are used to separate specific weed seeds and to clean certain pasture, vegetable and flower seeds. Fig. 3.5 presents an example of a sequence of seed processing machines for maize.

![Diagram of seed processing sequence for maize](image)

**Figure 3.5** Example of a processing sequence for maize (Gregg, 1983a)

**Plate 3.7** Seed cleaning unit, including an air screen cleaner (right) and an indented cylinder

**Plate 3.8** Gravity table of suitable size for laboratory use (courtesy of W.J. van den Berg)
Elevators
Since most cleaning equipment is fed by gravity, elevators are used extensively in seed-processing plants. These elevators should be such that they combine a high efficiency with a low rate of damage to the seeds.
- Plain belt elevators with moulded cross bars can be used for limited elevations.
- Augers are not very popular in seed processing because of possible seed damage and because they are difficult to clean between seed lots.
- Bar-type elevators are self cleaning but friction at the sides may still cause some seed damage.

- Bucket elevators are most commonly used for vertical transport of seed.
- Air ducts are a relatively new seed transport system. They are efficient and clean but seeds may get damaged at the tube connections due to the high velocity.

Blending
Blending is the mixing of seed lots (often, to combine one having a very high germination percentage with one of lower viability) to bring the latter to an acceptable standard. This practice is common with carry-over stocks. For instance, when a maize seed lot registers 80% germination and the lowest acceptable level is 85%, it can be mixed with a lot of equal size of 95% to raise it to approximately 87%. Though this practice may be discouraged in order to give the farmer seed of the highest possible quality, commercial considerations may prevail. A too high germination percentage could, however, also be detrimental to farming, i.e. when a thinning operation has to be carried out as a result of 'too high seed quality'. Normally, blending is only allowed when the components are of the same variety and seed class. When different generations are mixed, the blend will be of the lower generation class. A special case is the blending of different species of pasture seeds.

Blending can be done manually using a rotating drum or especially designed blending machines. The result has to be an even mix of the constituent seed lots.

Seed dressing
Chemical seed treatment is applied to protect stored seed through the distribution chain and during the early stages of
crop growth. 'Seed dressing' is a more generally used term and includes standard insecticide/fungicide treatments, pelleting, priming, and Rhizobium inoculation.

Pelleting is done for precision planting of small-seeded crops: chemicals can be included. Priming results in a controlled, early and homogeneous germination of the seed thus assuring an even emergence after planting. Rhizobium inoculation normally is done just before planting and is of importance mainly for leguminous crops. Chemical seed treatment is widely used and is, therefore, discussed in some detail. Details of equipment and chemicals, etc., are well covered by Jeffs (1988).

Pests and diseases can attack the seed in storage and in the field. A seed dressing of insecticides, bird repellents or fungicides, therefore, may be useful. Ideally, the chemical should combine the following characteristics:

- effective against all the major pathogenic organisms;
- non-toxic to plants and people, even if misused;
- environmentally safe (persistence);
- stable during the storage period;
- systemic in the plant to increase its effective life; and
- economically competitive.

Unfortunately, no such ideal seed dressing has been developed yet.

Insecticidal and fungicidal seed dressings should act against seed-borne diseases, storage pests and fungi, and soil-borne pests and diseases that attack the seedling and the plant in later growth stages.

Formulation
Powder dressings are used for dry treatments. A measured amount of chemical may be added to the bulked seed on the floor and the heap is then turned over using a shovel. A better blend is obtainable with a hand-rotated drum but the best simple option is an electrical rotating cylinder, although this method gives the highest dust levels. Compared with liquids and slurries, dry (dusty) formulations are hazardous because the fine dust in the treating area cannot easily be controlled. Most of the dust problem can be eliminated by applying powder dressings with an industrially-manufactured seed treater. Liquid or slurry dressings are the more common formulations because they provide more even distribution on the seed and are safer to handle. Various designs of seed treaters are available but a simple concrete mixer can also be used.

Chemicals
Seed-dressing chemicals contain: active ingredients, adhesive components, formulation components (solvents, etc.) and/or colorants.

Mercury compounds that were used widely as fungicidal seed dressings during the 1960s have proven to be very toxic and persistent in the environment. Currently, the insecticide Lindane and the fungicides Thiram and Captan are widely used, though Lindane is on the verge of being banned for most uses in Europe and the USA because of its environmental effects; seed producers elsewhere may find it difficult to buy the chemical in future. Alternatives have to be found which are less persistent in the environment and which have a reduced acute toxicity. The latter is of less importance in the Western world where well-designed seed treaters are used and handling and planting are mechanised. In many tropical countries, farmers sow by (bare) hand, unaware of the dangers and of the necessary precautionary measures of not eating or smoking while dressing seed, using gloves and washing thoroughly after touching the seed. Reduced acute toxicity, therefore, is extremely important. Normally, the seed dressing chemicals are combined with a bright coloured agent to warn the farmers of toxicity. This colorant can be used as an important factor in seed marketing.

A proper assessment of the value of seed dressing in relation to the cost of the treatment, has to be made for each seed type and for each lot, depending on its destiny. Ideally, seed treatment is done on order, i.e. just before being dispatched from the seed store.

Other seed treatments
Apart from seed dressing with agrochemicals, other seed treatments that have become popular in recent decades are pelleting and priming.

Pelleting is the coating of small and irregularly-shaped seeds with inert material, and the whole shaped such that each individual seed is contained within an entity of uniform dimensions. This allows for precision seeding and reduces seed waste, considerably. Such pellets can be combined with agrochemicals, including herbicides.

Priming is a pre-treatment of seeds to promote uniform germination. Seeds are allowed to germinate to the point where re-dehydration is just tolerated by the seed. When a farmer sows these seeds, they will all continue the germination process at the same moment, giving rise to a very uniform seedling bed. This technology is rather new: it requires a thorough understanding of the physiological processes in the seed and expert execution of the process. At the moment, priming is used for greenhouse crop seeds only. Details, therefore, go beyond the scope of this book.

Packaging
Seed packaging material should be strong, durable and well-labelled. In many cases, it also has to be a barrier to external moisture. Many different materials are used: for bulky seeds these are jute, woven polypropylene and multi-walled paper. An improvement on jute alone is its combination with a polyethylene lining (some moisture protection). Paper bags and jute bags are the most prone to rodent attack. For small quantities of vegetable seed, bags of various plastics, tins and aluminium-laminated packets are used. Though expensive, they give a high degree of protection against moisture and mechanical damage. The density and thickness of different plastics and their uniformity in quality, determine their permeability to
moisture. Air-proof containers are also effective protection against insect damage and even against storage fungi, since any oxygen in the tin is consumed by the insects, fungi and the seeds themselves.

The size of seed packet is an extremely important consideration in the distribution and commercialisation of the seed.

**Seed storage**

**Moisture**

The relation between seed moisture content and the relative humidity of the surrounding air has been described above. The importance of moisture in seed storage is illustrated by Harrington's (1960) rule-of-thumb that the life of seed is doubled by a 1% reduction of the seed moisture content. Once the seed has been dried to the appropriate moisture content, seed storage methodologies have to prevent moisture accumulation. The seed continues to produce water through respiration unless severe drying reduces these life processes to a minimum. In many cases, seed storage has to avoid access of moisture from outside. Especially for the larger seed types, it also has to secure sufficient ventilation to remove the moisture produced by the seeds themselves. Storage structures, therefore, have to have a proper roof, a layer of sealant (e.g. bitumen paper) built into the floor, over-hanging eaves to protect the walls from rain, and sufficient facilities for ventilation. For high-value low-volume seeds (many vegetable seeds and nucleus seeds of any crop) air-conditioned stores equipped with dehumidifiers are suitable.

To provide the necessary ventilation, seeds should be stacked on pallets such that the width of the stacks is limited and no containers touch the walls. These measures also aid seed stock administration, allow room for quality monitoring of seed sampling and reduce vermin damage.

For recalcitrant seeds (e.g. rubber, cacao) dry storage is not possible. Despite some other seeds' tolerance of drying, e.g. soya bean in the hot humid tropics, seed storage may be one of the major bottlenecks in crop production (Linnemann & Siemonsma, 1989). A rather extreme solution to this problem is presented by Henning & West (1993) who showed that a PVC co-polymer coating extends the storage potential of soya bean seed. This 'plastic wrapping' of individual seeds acts as a barrier to moisture.

For many legumes and okra, warm and dry conditions result in 'hard' seeds. These hard, impermeable seeds do not germinate readily when planted but they do remain viable for a long time. This is an obvious advantage for survival of the species but not very advantageous for crop cultivation.

**Temperature**

Harrington (1960), developed a rule-of-thumb on the relationship between temperature and seed storage: the life of seed is doubled for each 5°C reduction of storage temperature (between 0°C and -50°C). Temperature, however, is more difficult to manipulate than is moisture. Except for the ventilation requirement mentioned above, often it is not economically feasible to reduce the storage temperature for bulked seeds. In mountainous areas, transportation of the seeds to higher elevations may be an alternative, provided the relative humidity of the air at higher elevations is suitable. For low-volume, high-value seeds, cold rooms may be a suitable option. It must be borne in mind, however, that a dehumidifier will be required in the cold room if the seeds are stored in permeable containers.

Long term storage of seed (genebanks, Breeder Seed) can be done best in sealed containers, if necessary, with the addition of silica-gel for extra dehumidification at reduced temperatures.

The relation between temperature and relative humidity is given in the psychrometric chart (Fig. 3.6) which is an important tool in seed storage management. From this chart can be calculated the relative humidity of the air at a given temperature measured with a wet-bulb/dry-bulb thermometer. Relative humidity is linked with the equilibrium moisture content of different seeds after storage (Table 3.6) which, in turn, determines their storage life. The dry-bulb temperature (Tdb in Fig 3.6) is the normal ambient temperature: the wet-bulb temperature is measured with a thermometer the mercury reservoir of which is covered by a moist cotton cloth. Evaporation of the moisture from the cloth reduces the temperature of the wet bulb. The rate of evaporation and the size of the concomitant drop in temperature depends on the relative humidity of the surrounding air. The moisture content of the air (MC) is also temperature dependent and can be included in the calculations.

**Insect infestation**

Storage insects, such as grain weevils (Sitophilus zeamais and S. oryzae) grain moth (Siotroga cerealella) and Tribolium, can damage stored cereal seeds. Bean bruchids
Figure 3.6 The psychometric chart

(Zabrotes subfasciatus and Acanthoscelides obtectus) damage beans and related seed types. The harmful, lesser and larger grain borers (Rhyzopertha dominica and Prostephanus truncatus, respectively) have spread to various regions in Africa. These insects can be controlled by fumigation (e.g. with phosphin), store hygiene and seed treatment. Hygienic storage conditions are determined by the actual cleanliness of stores and also by the absence of important storage insects and their feeding grounds in the direct vicinity of the seed stores (and conditioning plants).

Continuous monitoring of the stores for the presence of storage insects and a proper diagnosis of any problematic insects, are vital. For example, Pyrinphos-Methyl (Actellic) is used widely, in East Africa, for the control of storage insects in maize: when the larger grain borer invaded an area, however, this chemical contributed to an increase in the spread of this insect by reducing its competitors.

Some storage insects can infest the crop in the field. Good husbandry practices in the later stages of the crop’s production period can greatly reduce any initial population brought into a store. Such practices include timely harvesting, hindering the pest’s entry into the grain by reducing bird damage and, in the case of maize, plantin varieties with a good husk cover. Fumigation and general store hygiene will further reduce insect problems during seed storage.

Optimum conditions for the grain weevil are temperatures of 25-27°C, and 70% relative humidity. Under such conditions, the total development cycle from adult through egg, larval and pupal stages lasts from 31 to 37 days. Each female can lay up to 150 eggs within the first month of adult life, so the build-up of a large population can occur fairly quickly if no preventative measures are taken.

Grain moths can complete a life cycle in 28 days. The larvae bore into the grain where they continue developing until emergence of the adult. Adult moths mate and lay eggs within 24 hours of emergence from the pupae. Since larvae are relatively immobile and the winged adults cannot penetrate deep into the grain, moth infection is restricted mainly to the surface layers of the grain stack.

Management
Seed store management involves practical decision making and proper administration. For every seed lot with a known germination percentage, a storage period can be estimated when temperature and relative humidity of the air are known (Kraak, 1993). These are generalisations, however, because
they are based on constant storage temperatures and do not take varietal differences into account. Large temperature differences between day and night can cause enough condensation on the seed to affect seed storage. Also, Zanakis et al. (1993) showed that varietal differences in seed longevity can be significant.

These factors form the basis of decisions on storage methods and lot dispatch. A general rule is that seed lots are dispatched in the order in which they entered the store (first in - first out) but more flexibility in decision-making may be necessary. The status of the seed determines whether intensive ventilation is required. Proper analysis of the underlying deterioration processes in the seed gives a good basis for investments in seed storage facilities. A reduction in seed moisture content may have the same positive effect as a reduction in storage temperature. In most cases, investments in seed drying are more cost effective than are installations for cooling.

Seed marketing

Market components

The market

The market consists of four basic elements: the producer, the product, the customer and the competitor. Marketing has to optimise the variables in order to reach the established objectives (see marketing strategy below). Although seeds are a rather special commodity, the following general factors give a good starting point for seed marketing discussions:

- Definitions of consumer needs and consumer purchasing power have to be combined with short- and long-term company strategies with regard to breeding and production of seed of the various crops and varieties.
- Definition of geographical distribution and collection of information on potential customers will determine the transport and distribution systems, and the method and timing of promotional activities.
- Definitions of the profitability of the crop, the quality of the product and the level of competition will define the pricing structure.
- The pricing structure, in turn, affects the size and geographical distribution of the actual market. The price may affect the quality that can be delivered and vice versa. This is why optimisation of variables is required.

The producer

Seed marketing should take into account the limitations of its own seed production organisation, including the time required to breed new varieties that fit into a market and the time required to bulk sufficient quantities of Certified Seed. Staff of the other sections of the organisation may have very different professional backgrounds and perceptions of the bottlenecks in the seed supply chain, so good communication between sections is essential.

The product

Seed is living material: it is delicate and during transport and storage is vulnerable to damage by temperature, moisture, chemicals and biotic factors. Its value is determined by the various quality factors and by the management of the farmer with respect to land preparation, timeliness of planting and weeding, and the use of other inputs such as fertiliser.

The value of seed cannot be assessed only by sight, smell or touch; the consumer, therefore, has to put a great deal of trust in the supplier and the dealer.

A particular variety's popularity typically follows an optimum curve with respect to time. It will attract a good market after initial introductions have proved positive. The market share that the variety gains and the period that it maintains a significant share, largely depend on biotic factors (e.g. diseases) and on the relative research capacities of the competitors and the parent organisation.

The customer

It is vital to understand the behaviour of the farmer with regard to adoption of technologies, and a thorough knowledge is required of the constraints that a farmer faces in the production of his crops. Along with these more technical features, the role of beliefs, notions and customs, and the influence of the community on the farmer's thinking, should be understood. One of the main issues in seed marketing is the geographical spread coupled to the often very limited mobility of the target group. Both promotional activities and the seed itself have to be placed within the 'zone of mobility' of the farmer.

The competitor

Competitors in the seed business in tropical countries are not always well defined. A competitive market situation with other (private) seed producers, is rare. Thus, national seed organisations have a virtual monopoly. For nearly all crops, though, there is at least one real competitor: the farmer himself (Kloppenburg, 1988).

A seed producer has to compete with farm-saved and locally-bartered seed. He has to offer seed of a higher quality, in the right place and quantity, at the right time and at an acceptable price. Because farmers are not always regarded as being serious competitors, poor seed production planning and marketing strategies may result.
Marketing the seed
Marketing activities include the establishment of a marketing strategy, market research, market communication, pricing, logistics, distribution and selling.

Marketing strategy
A marketing policy includes very general long-term statements regarding the different activities of the seed company as they relate to the market and to marketing itself. The most general decision that has to be made regards the part of the market that will be the focus of the company's activities. This basic question determines the course of action of the whole seed enterprise. Will the company aim at a small high-value market or a large market with lower unit profit or, in management terms, at either differentiation or cost-leadership (Porter, 1980)? Concentration on the former involves increased research investment, top quality commodities through intensified internal quality control, excellent packaging, short distribution channels, and servicing a market that is willing to pay a price for quality. Concentration on the latter involves large volume production with acceptable quality and a limited mark-up per product unit. A related consideration is whether the company aims at short-term gains or a long-term market.

More detailed aspects of a marketing strategy include, for example:
- the basic method of obtaining market information for production planning;
- the main features of the distribution chain (company-owned stores or private wholesaler and retailer networks, and company- or hired transport, etc.);
- the basic elements of the price policy such as differential price structures within the distribution chain and the choice between controlled or free prices at retail level; and
- the percentage of sales revenue used for marketing in general and for promotional activities in particular.

Such marketing-strategy statements should be as stable as possible to serve as operational guidelines. At the same time, they should be flexible enough for instant modification when required by changing circumstances.

In tropical seed production, various objectives related to national policies may distort the company strategies. National food security through increased use of improved seeds, and regional rural development through increased cropping targets, are well known objectives with which a seed production manager may have to cope. Such national policies generally result in a downward pressure on seed prices and a great fear of shortages in the seed market. This applies as much to commercial seed company planners as it does to managers employed by government or parastatals: none is free from public pressures (Chapter 4).

Market research
Market research analyses the prospective market with regard to potential customers and competitors. It is important to know who are the customers, their whereabouts, their varietal requirements and the quantities that they are likely to buy at any particular price. Demand forecasts for the short term can be derived from these results. Such forecasts facilitate production and distribution planning, preparation of cash flow and general budgets, and the assessment of possible necessary price adjustments. Long-term demand forecasting is required as a basis for investment.

Since seed is a production input, the seed market of food crops depends to a large extent on the food crop market. This makes demand forecasting very difficult. A sudden boost in an export market for a specific crop may generate a concomitant demand for seed. The seed market will also respond to the general economic situation of the farming community as it is affected by national policies. Regional differences, also, may greatly affect the marketing potential. A poor harvest in one area of the country may generate a specific demand: one which could not have been predicted when national figures were compiled.

Seed market research also has to monitor the performance of the varieties. A build-up of a disease in a variety may have a dramatic effect on the demand for seed of that variety and of its alternatives.

Collection of these important data is not easy in areas where, characteristically, communication lines such as telephone and postal services are unreliable, where statistical data are scarce and where extension services are not effective.

The needs of a farming community may be very specific due to geographic, cultural and economic segmentation. Differences may be more notable in developing countries than in industrialised countries where growing conditions are more uniform as a result of mechanisation of agriculture and food processing. This segmentation may result in a wide product range: more crops and varieties per crop. The number of varieties that can be produced economically by a seed enterprise needs to be limited, however (see seed production planning below). With regard to varieties, the concept of the product life cycle is important. The following stages can be discerned:

i. The sales of a new variety rise at a rate that is determined by the appropriateness of the variety and the promotional activities.

ii. Sales reach a peak, the dimensions of which depend on the size of the potential market (the area in which the variety performs), the average seed replacement rate and the effectiveness of competing local diffusion channels.

iii. Market saturation occurs, followed by a decline determined by the speed of introduction and relative value of newer varieties, and declining old varieties due to broken resistances or changing farming techniques.
The length of the product life cycle differs very much depending on the area and the individual variety. Keeping track of sales records, while keeping in mind the general stages of the cycle, gives important insight into the marketing prospects of a variety.

Figures 3.7 and 3.8 each illustrate different varietal life-cycle scenarios in relation to their competitors. The situation in Mexico (Fig. 3.7) shows a quick replacement of varieties. Figure 3.8 shows the development of a clear market leader 'Yecora', which is gradually replaced by several new varieties after a number of years. A seed marketing office would like to be able to predict such trends.

In general, the most reliable information is received from the seed distributors rather than from the extension service. The former can be encouraged to make their own forecast by offering discounts for advance orders. In practice, however, orders tend to be placed as late as possible to avoid the cost of maintaining stocks (lock-up cash) and to accommodate the usual practice of deciding on a cropping pattern according to the timing of the rains (Fris-Hansen, 1992).

Rowland (1993) describes this marketing problem as follows:

The main generator of demand for seed in drought-prone areas is seed loss due to crop failure or seedling mortality. . . . At such times there is heavy demand for seed at very short notice. There may not be time to distribute seed in response to such emergencies. Drought-generated demand of this kind is highly unpredictable and tends to alternate with one or more years of low demand.

Using the national acreage of a certain crop as the basis for seed market assessment, hardly ever provides satisfactory results (Vandevenne & Bono, 1987 and various seed project consultancy reports). The seed market is far more complex. Using past sales records as a basis is often much more reliable and reduces the level of wishful thinking to a minimum. It is very important, therefore, that the results from each seed marketing campaign are analysed thoroughly.

**Market communications**

It is important to have good communication links with the farmers, to inform them of the availability and the quality characteristics of the seed (information) and to create the desire and willingness to purchase the seed (promotion). Gregg (1983) summarised the above in the AID ME concept:

Farmers should be made AWARE of the existence of improved seed; INTEREST should be aroused; and the potential should be DEMONSTRATED; then farmers should be MOTIVATED to try the improved seed and should be EDUCATED regarding how to combine it with other inputs and how to obtain the necessary credit.
Figure 3.7  Wheat variety replacement in the Yaqui Valley, Mexico, 1977-1988 (Helsey, 1990)

Figure 3.8  Wheat variety replacement in the Punjab, 1978-1987 (Helsey, 1990)
The promotional activities should create transparency of the market. Messages should be realistic and farmers should be able to confirm the promises made. Official variety performance test results can be a great asset to a seed company. The manner and intensity in which the messages are passed on to the customers can give an added value to the objective information, such that one can speak of 'promotion'.

Selecting the appropriate media for information dispersal and promotional activities in the seed trade, is vital. Targeting the different types of seed for different types of farmers is necessary. Many farmers of hybrid maize can be reached with television and newspaper advertisements, and public relation activities may influence them. Growers of open-pollinated beer type sorghums can be reached by using posters in the local languages (which increases the cost of this type of promotion) and through clear and consistent logos on billboards, buses, cinema slides and seed packs. The colour of the treated seed can also be an important 'trademark'. The Kenya Seed Company uses a green dye in the dressing and thus, in East Africa, green maize is associated with the varietal and other seed qualities of the products of this company. There is a danger, though, that such a trademark can be easily reproduced or that dyed food grain is sold as hybrid seed. Unfortunately, this is a (too) common practice.

In general, demonstration plots are a very effective means of getting the message across to the prospective customer but they tend to be very expensive. They may be actual crop demonstrations, at the extension headquarters or in farmers' fields, or sales demonstrations at local fairs and markets (linked to mobile distribution as proposed in the Eastern Province of Kenya). Such demonstrations have to be organised regularly in order to build confidence and to keep the extension staff and local prominent people involved in the seed issue'. In some cases, it can be highly effective to link the promotional activities of the seeds to those of other inputs, such as fertiliser. This, however, could also negatively affect sales. For example, when maize seed is advertised together with fertiliser it may be understood that the groundnut seeds carrying the same company label also require such inputs.

**Seed pricing**

High-quality seeds are valuable and should be priced accordingly. Price ratios of 1 : 1.8 for grain and seed respectively (for self-fertilizing cereals and legumes) and 1 : 4 or 1 : 6 for open-pollinated varieties of crops like maize and sunflower can be attained if the quality of the product does indeed give the farmer sufficient returns on his investment. Newly-introduced varieties of self-fertilizing crops may fetch a slightly higher price factor than 1.8 until the variety has spread widely. For hybrid maize, seed prices may be even higher (12 - 18 times).

The multiplication factor is important, but so also are the level of organisation of the grain marketing system in the area and the level of home consumption. In seed production in the tropics, problems arise rather often as a result of insufficient attention to seed pricing. In government systems, the price is usually fixed as a cost-plus price. Such a pricing system does not bear any relation to the market and may be lower or higher than necessary, depending on the situation. It may be high as a result of inclusion of depreciation on excessive investment (as a result of donor-assisted projects) and the cost of inefficiency. It could also result in an underestimation of the value of the seed if, for example, the cost of capital is not included or if, in a high inflation situation, calculations are made according to cost factors of the previous season. This then results in insufficient revenue and the continuous need for fresh capital injections into the seed system. It can even happen that the seed price drops below the production price either as a result of the normal annual price fluctuations between the surplus harvesting period and the short supply of grain at planting, or due to the often extreme inflation in combination with the above principles of price fixing. The result may be that certified (and sometimes chemically treated) seeds are consumed. This situation can also arise when seeds are distributed very cheaply as relief aid.

According to Louwaars (1980) if farmer-saved seed is the major competitor, the maximum market price of Certified Seed sales depends on the following factors:

- **The mating system of the crop.** Competition from home-produced seed is higher for self-fertilizing and vegetatively-propagated crops and lower for cross-fertilizing crops, especially hybrids. 'Compared to hybrid seed, sales and profits from non-hybrid seed are heavily dependent on commodity prices and face competition from farmer-saved seed. As a result, the margins are narrower and contributions more subject to year-to-year fluctuations.' (Pioneer, 1990).

- **The multiplication factor of the crop.** For crops with a high multiplication factor (e.g. sorghum and sunflower), the seed price may be 10 times the grain price, whereas for a crop like groundnut (mf = 10) a seed/grain ratio of 10 : 1 would render crop production uneconomic from the very start. The prospects for an interesting seed price are thus much higher in crops with a high multiplication factor.

- **The level of market orientation of crop production.** Crops that are mainly home-consumed are not likely to fetch a commercial seed market, especially where a variety of local preferences can be identified. Seeds of highly commercial crops, like vegetables, are generally easier to sell although seeds for the home gardens are also mainly home-produced.
Crop-specific factors may increase the seed price level. Examples of such factors are: difficult-to-store seeds like soya bean or dent maize in humid tropical areas; a high incidence of seed-transmitted diseases (potato); seeds that are difficult to produce, such as pasture grasses, many vegetables and legumes; and specific advantageous seed treatments such as insecticides against stem borers of sorghum, fungicides against seedling diseases of vegetables, and inoculants of legumes.

Field beans are self-fertilizing and bulky (low m³), largely home-consumed, and local preferences can be very specific. Commercial seed prices are not accepted by farmers and formal bean seed production is very rarely viable (Grisley, 1993). Delouche and Baskin (1982) claim that seed should result in a 20% yield increase before farmers are likely to invest money therein.

Logistics, distribution and selling

Transport of seed requires very careful planning because of the tight time schedule that often applies to a seed campaign before the season. Because of the seasonality of such a campaign, it is hardly ever cost-effective for seed producers to maintain their own transport fleets. Contracts with local transporters have to be made early, though, to avoid distribution problems. The use of 'return capacity' from produce hauliers can be very beneficial. To reduce the overall planning, the use of distributors (wholesalers) between the company and the retailers may be necessary, especially in larger countries. This applies less to vegetables which, generally, are less seasonal, not bulky and have a high value. The wholesaler can play an important role in the seed marketing activities. He is best equipped to oversee the whole chain, i.e. the demand at the retail level and the supply at the seed company level. The wholesaler could thus be the 'channel captain' of the industry.

Improved packaging (e.g. tins, laminated packages) can increase the shelf life of the product significantly and gives the distributor an increased flexibility.

A wholesaler and retailer network is an essential element in seed marketing. The dealer density has to be cost-effective and correspond to the mobility of the customers, i.e. high enough to reach sufficient farmers and low enough to avoid excessive transportation costs in effecting timely delivery.

The retailer often acts as an extension agent for agronomic advice. This is important, because the seed will be most profitable for a farmer if combined with proper practices. It is thus in the interests of the dealer (and of the seed company) to render such services and thereby establish the necessary confidence. For this reason, seed retailing is often regarded as a task of the public extension service. Even though extension staff may be geared to render these services to the farmer, the organisation is seldom sufficiently oriented to the commercial aspects of retailing seed.

Dealers should be trained and the training should include:

- the knowledge of quality aspects of seed, in general, and the agronomic aspects of the crop and variety, in particular;
- the knowledge of seed store management, product display and the use of publicity materials;
- the monitoring of the performance of the seed and regular record keeping; and
- the importance of monitoring competition posed by other seed enterprises, and of honesty in business.

Such training sessions are also very useful in getting feedback on farmers' preferences with regard to varieties, seed-pack size, etc. The breeders, therefore, should use such meetings to the maximum.

Various discount systems in cash or kind are highly effective in establishing a good and long-term business relationship with both wholesalers and retailers.

In general, seed sales of rain-fed food crops are concentrated in a very limited period of the year (or two periods in case of bimodal rainfall patterns). A seed retailer, therefore, will have to have other business interests. Often, it is considered most appropriate to attract retailers that already have dealings with the farming community, such as dealers in agrochemicals. This combination of products (chemicals and seeds) bears a danger, however, of conditional sales (packages) which may not be in the best interests of farmers. In areas where farming is not highly commercialised, such dealers may be sparsely distributed and the local 'soap and matches' shops can be very effective substitutes. These are also reasons why seed company retail shops are rarely the best distribution option.

Plate 3.13 Retail selling of maize in Kenya (courtesy of A.J.G. van Gastel)
Local Farm Supply, or Produce Trade Cooperatives, can be very effective as seed dealers. They have the advantage that they have a close contact with the farmers and that they can also carry out part of the distribution operations. A disadvantage is that, in many countries, the cooperative system lacks financial liquidity. Development projects of governmental or non-governmental organisations can be very effective distributors since they seldom have financial liquidity problems and can pay in advance. This option is used widely in The Gambia. The limited active life of such projects should pose some concerns about the sustainability of such distribution channels, but they are specifically effective for the development of new markets.

Linking seed distribution and sales with other distribution networks can be highly effective. Seeds are distributed through a soft-drink marketing channel in Nigeria. Petrol stations could also be good distributors, especially in areas where truckers may carry a 'return load' to remote areas. It must be borne in mind, however, that petroleum products can affect seed viability and that treated seeds should be kept separate from food stuffs. Grain traders are potentially effective seed distributors especially where certain quality characteristics, such as pure white sesame seeds, are preferred. They can sell seed when paying farmers for their produce. The haphazard nature of the produce trade may, however, negatively affect the build-up of the farmers' confidence in the product and the producer.

The same type of product may be sold through different channels in different parts of the country due to various local differences. Maize seed can be sold through a coffee cooperative in one area, through hardware shops in small towns in areas with slightly larger farms and through village 'soap and matches' shops in more remote areas.

A last option, i.e. when all the others fail, is distribution through the government extension service. This option is almost automatically chosen in emerging (government) seed projects, but is seldom effective if used without proper incentives.

Seed price is an important instrument in the construction of a seed marketing system. The profit margin for the retailer has to be interesting enough for him to stock the product and advertise its availability. Incentives can be built into the pricing strategy in order to promote early and bulk delivery to the retailers, thereby reducing the strain on the logistics during the campaign leading up to the start of the season. The importance of good profit expectations for the operators of the marketing chain is often overlooked in seed projects in the tropics. The Kenya Seed Company was an exceptional example. It introduced a vigorous and well-perceived marketing system for its seeds in the 1970s, thereby managing to reach even a considerable number of smaller farmers with hybrid maize. This success, to a large extent, is due to attractive margins offered to retailers (Verbrugt, 1982).

Seed quality control

The major objective of seed quality control is to prevent low quality seed being available on the market. A complete formal seed quality control system comprises the following operations:

- Certification (involving inspection of fields, processing plants, stores and markets) and labelling in order to confirm the origin and varietal purity of the seed lot;
- Seed testing, involving sampling, viability and germination analysis, purity analysis, moisture analysis, seed health testing, and vigour tests; and
- Post control, to give a final judgement of the seed lot, to check on the quality control operations and to act as an examiner of possible complaints.

The organisation of the seed quality control operations greatly affects their reliability and efficiency.

Certification

The main techniques applied in seed certification are:

- Introducing a strict generation system and controlling the origin of all the seeds that are sown in the seed certification scheme;
- Setting standards for the scheme's control operations;
- Inspecting seed fields, to check on the origin of the seed planted for multiplication, the phenotypic purity of the variety and the disease and weed levels in the seed fields; and
- Avoiding uncertainty about the identity of a seed lot after harvest by labelling.

Seed classes

The number of generations used in the certification system is fixed at the lowest possible level because the genetic value of a seed crop can, in principle, only decrease from one generation to another. The Breeder Seed class has to be considered the maximum obtainable genetic purity level. Different seed classes are labelled with differently coloured labels for easy identification.

Standards

Standards are set for field inspection, (including varietal purity/off-type counts), isolation from potentially contaminating crops and permitted disease and weed levels. Seed fields that fail to reach these standards are either downgraded or rejected for seed purposes. The standards are arrived at by striking a balance between the maximum obtainable quality and the required seed quantity. Optimum levels of seed quality should be set in such a way that a reasonable percentage of the seed producers can meet standards that are strict enough to promote the quality aspects of seed production. Malki (1994) reports that, on average, 40% of Algerian seed crops are rejected. This could
be because of poor farming at the contract growers’ level or because of unrealistically high standards.

Table 3.7, drawn from Wellving et al. (1984) shows the different requirements for seed of self-fertilizing crops (e.g. wheat and cowpea), wind-pollinated crops (e.g. maize and pearl millet) and insect-pollinated crops (e.g. sunflower and onion). It is remarkable that rather high isolation distances are required for self-fertilizing crops such as lettuce, common beans and groundnut and that the required isolation distance for open-pollinated sunflower (strongly cross-fertilizing) is so much less than for cotton for which the percentage of cross fertilization is generally much lower. It could be that distant isolation for sunflower is not feasible and that standards for important export crops like cotton and tobacco are higher in order to maintain export quality standards. The standard percentage of undesirable plants is rather academic. For newer and old varieties, tolerances for acceptable numbers of off-types could be built in. Disease tolerances are not well described.

When isolation distances pose serious practical problems in seed production, buffer crops and time isolation may be used to reduce the distances required with cross-fertilizing crops.

**Buffer crops**
In wind-pollinated crops, unwanted cross pollination is most severe at the edges of the field, especially those on the windward side of the field. The inner parts of the field are protected by the vast quantities of pollen that are produced within the field itself. In various certification schemes for crops like maize and sorghum, reduced isolation is allowed when the outer rows of the seed production field are not harvested for seed (e.g. a five metre buffer may reduce the isolation for sorghum from 200 m to 150 m) but such standards may also depend on the relative sizes of the seed field and the neighbouring field of the same crop. A one hectare Foundation Seed field should be protected very well from a 100 ha grain crop, whereas the same seed field may not suffer very much from a neighbouring home garden with 10 plants. In practice, however, strict instructions are necessary for field inspectors and fixed rules have to be set to avoid confusion.

**Time isolation**
Another method to reduce isolation distances is time isolation. This means that crops can be planted within the physical isolation distance of the seed crop as long as flowering periods do not coincide with that of the seed crop. This strategy can be dangerous for open-pollinated populations in that flowering may occur over an extended period. It may, however, be the only way to isolate crops with very large isolation-distance requirements, e.g. sunflower and onion whose uniformly flowering varieties and hybrids can be isolated in this way. Special attention has to be given to the fact that the exact flowering date depends not only on the variety and the sowing date but, also on the particular ecological conditions. A safe margin has to be used when practising time isolation. In practice, this is mainly for small fields of (Pre) Basic seed, planted under strict supervision.

**Field inspection**
It is the task of the seed quality control unit to increase the quality of the seed that reaches the farmer. This can be done through policing seed production, through advice to seed growers on how to solve and how to avoid problems relating to seed quality, or through a combination of both. The field inspectors play a major role in deciding which course is best.

A field inspector checks on the seed used for planting, confirms the area and variety planted, checks isolation, calculates the plant population in order to assess off-type and disease percentages, identifies possible noxious weeds in the field and evaluates the general crop husbandry and the expected yield. This is done during various visits to each seed field during the cropping season, especially:

- **before sowing**: cropping history and general suitability of the field, variety and generation of seed to be planted;
- **at flowering**: off-types, isolation, cultural practices;
- **before harvesting**: final check on the field and yield estimate; and
- **after harvesting**: threshing, storage, sampling, and affixing transport labels.

The yield estimate before harvesting fixes, within a certain range, the quantities that will be delivered. It is done to prevent deliberate mixing of seed from other fields with that of the seed crop. This can be expected to happen when the farm gate price for raw seed is much higher than the produce price. The field inspectors cannot detect every instance of this kind of fraud. Post-harvest control checks, however, are likely to expose the most serious culprits.

Yield estimates can be made by experienced inspectors only. The plant population, disease pressure and general appearance of the crop should be taken into account, together with the yields that were obtained in the area in the past. For minor crops like vegetables, a complete system of field inspections is seldom applied because of the wide range of crops and the small areas of seed production involved. In developed countries, quality control activities are often delegated to the producer and only random official checks are made.

**Labels**
A provisional label (for seed quality control purposes only) which states the variety, season of production and grower, should be attached to each seed container immediately after threshing. This transport label is used to identify the seed lot while it is awaiting transport to the processing plant.

After processing, several small seed lots of the same variety but from a number of different seed growers may be combined to form an official seed lot. A lot number is given to any such thoroughly mixed blend of up to a
### Table 3.7  Field Inspection standards for Zamla

<table>
<thead>
<tr>
<th>Crop</th>
<th>Isolation distance (m)</th>
<th>Undesirable plants (%)</th>
<th>Minimum number of Inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-B</td>
<td>C1</td>
<td>C2-3</td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP</td>
<td>400</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>inbred line</td>
<td>800</td>
<td>400</td>
<td>-</td>
</tr>
<tr>
<td>Wheat</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Barley</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Rice</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP</td>
<td>400</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>inbred line</td>
<td>800</td>
<td>400</td>
<td>-</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP</td>
<td>400</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>inbred line</td>
<td>800</td>
<td>400</td>
<td>-</td>
</tr>
<tr>
<td>Finger Millet</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Field Bean</td>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Pea</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Soya Bean</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cowpea</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Groundnut</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Sunflower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP</td>
<td>800</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>inbred line</td>
<td>3000</td>
<td>15500</td>
<td>-</td>
</tr>
<tr>
<td>Onion</td>
<td>3000</td>
<td>15500</td>
<td>1500</td>
</tr>
<tr>
<td>Okra</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Cotton</td>
<td>1000</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Tobacco</td>
<td>800</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Lettuce</td>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Source: Welvving et al., 1984

** Hybrid seed production:
A. Not more than 0.1% undesirable 'male' plants at commencement of pollination (= when less than 5% of the plants have apparently-receptive silks)
B. Not more than 0.25% of pollinating or otherwise undesirable 'female' plants at any inspection.
C. Not more than 0.1% off-type cobs or seeds.

** As for maize (where applicable).

The maximum of 20 tonnes (for most crops). The lot number, generally, consists of a series of codes; an example of an Ugandan lot number is 2/KWCA/F/2/91. It indicates that the seed lot was produced at Kisindi Seed Farm (code = 2) that it is variety KWCA (i.e. maize) Foundation Seed class (code = F) and that it was produced in the second season of 1991. This avoids duplication of numbers and, hence, confusion. When two lots have been produced at the same farm, an extra numerical code can be added.

**Labelling of seed lots**

The OECD uses the following colour codes for different seed classes:

- Pre-Basic Seed: White with diagonal violet stripe
- Basic Seed: White
- Certified Seed of first generation: Blue
- Certified Seed of second generation: Red

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Figure 3.9 illustrates an example of a seed label from Sri Lanka. Note the various categories of printed information: crop name, variety, lot number, date of sealing, minimum germination percentage and quantity. On the reverse, there is a short explanation of the label. The label indicates that the seed has met the minimum certification and seed testing standards. US-system labels state the actual germination percentage and purity of the particular seed lot.

Other aspects of Fig. 3.9 that are of note are:

- The information is written in all major languages of the country (in this case, English, Sinhalese and Tamil).
- There are two labels on each bag: one on the outside the bag for identification and information and a copy inside the bag for confirmation (and as a back-up should the outer label be lost). Since the labels shown in Fig. 3.9 are used with jute bags, one label is sealed in the bag after which the outer label is affixed. When polypropylene or paper bags that can be stitched are used, the label can be affixed and the bag closed in one operation such that the information of the outside part of the label will be summarised on the inside part of the same label.
- Each label has an individual number so that the history of every individual seed packet can be traced.

Processing facilities are inspected throughout the factory operation. The main checks are on proper cleanliness of the machines, most importantly, when changing varieties and crops.

Maintenance of the quality of the seed is highly influenced by the method of storage. Temperature, humidity, storage diseases and pests can reduce viability in a relatively short time (Chapter 1).

Seed inspectors, therefore, need to check seed storage properly and, in particular, the labelling of the seed lots. Primarily, certification deals with the proof of origin of the different seed classes.

**Plant and store inspection**

Seed inspectors also check on a number of other aspects related to seed quality:

- **storage structure** - whether or not there are any signs of leakage;
- **administration** - whether the book-keeping is accurate with regard to quantities and seed lots stored;
- **stacking** - use of proper pallets and seed stacks placed well away from the walls;
- **pest management** - whether or not the store is kept clean and there are signs of rodent or insect infestation; and
- **quality assessment** - the inspector may sample the seed lots during storage to monitor the viability and other quality aspects.

**Marketing control**

In highly regulated seed production programmes, intensive marketing control has been developed whereby inspectors visit each retail outlet on a regular basis to check samples for maintenance of standards. Labels are re-validated as necessary depending on the seed testing results. This requires a large investment in manpower and transport which may be better directed towards training of wholesalers and retailers in seed quality awareness.

**Seed testing**

Seed testing is done to assess the physical, physiological and sanitary quality of the seed. It is done by trained staff in a laboratory. The design and requirements for such a laboratory in the tropics, have been described by Heuver et al. (1979) and Van der Burg et al. (1983); equipment designs are presented, by Madsen (1984; 1985) for the International Seed Testing Association (ISTA). Various tests can be done in a routine manner to assess seed qualities: all depend on proper sampling and sub-sampling methods.

The main tests are purity analysis, germination and viability tests, moisture analysis and seed health tests.

**Standards**

The test results refer to established national standards for the specific seed qualities (which differ with crop and may differ between countries). Seed standards strike a balance between the maximum seed quality (100% germination and purity, and no diseases) and the practically-obtainable seed quality. Because of prevailing weather conditions a certification agency in one country may have to accept a standard for seed moisture content of a particular crop of 13%, whereas an agency in another country may reject any seed above 12%
Figure 3.9 Sri Lankan seed-certification label (front)

**SEED CERTIFICATION SERVICE, DEPARTMENT OF AGRICULTURE, PERADENiya**

1. The S.C.S. indicates that the Sri Lanka Seed Certification Service has inspected the crop in the field and has drawn a sample of the seed.
2. The result of the analysis can be obtained on application from the supplier of the seed or from the S.C.S.
3. This seed was issued in accordance with the seed rules which govern this crop.
4. The minimum germination percentage on issue is valid on the date of issue.

Figure 3.9 Sri Lankan seed-certification label (rear)
moisture. In general, standards for higher generation seed classes are more stringent than for the certified class.

Realistic cost-benefit assessments have to be made when setting seed-testing standards. A germination percentage of 75% may be realistic if 85% would be very difficult to attain and hence be more expensive or available only in small quantities. The certification agency should also have the flexibility to alter standards when the seed supply is at stake, e.g. when a very wet season increases the seed moisture content of all the seed and strict application of the standard would mean rejection of the whole seed stock.

The only issue for which rigid standards have to be applied is seed health of imported seed (phytosanitary control). A flexible standard here can lead to absolute disasters.

**Sampling**

Sampling of seed lots is normally done by the inspector. A seed lot may not be fully homogeneous because of insufficient blending of the different lots produced by individual farmers, or due to the storage conditions which differ (with regard to ventilation and insect infestation) between the centre and outside of a stack. The objective of sampling, therefore, is to obtain a small quantity of seed that is representative of the whole seed lot. If it is assumed that the weight of 100 soya beans is approximately 20 g, then there are 100 million seeds in a 20 ton seed lot of that crop. Only 400 seeds are tested in a germination test, i.e. only one out of 750,000 seeds is being checked. It is obvious that correct sampling is of the utmost importance for reliable seed testing.

Primary samples have to be taken from different seed bags and at different levels. Depending on the size of the lot, ISTA prescribes the number of primary samples that have to be taken to arrive at a representative 'submitted sample' (ISTA, 1993). It is important that the inspector has free access to the different bags in the lot. Stacking against the wall, or stacking in such a way that all bags are facing the same way, may result in rejection by the inspector as he is unable to draw a representative sample.

A working sample has to be drawn at random from the submitted sample for the seed testing exercise. Various methods for achieving this are applied - mechanical dividers (conical, centrifugal or soil divider), random cup method, modified halving method or spoon method (Feistrizer, 1975). These working samples can be used for the actual seed testing (Fig. 3.10).

**Moisture testing**

Seed moisture is one of the most important parameters affecting longevity during storage. Testing of this is necessary, therefore, at various stages in the seed chain; before harvesting in order to assess whether the optimum harvesting (and threshing) moisture content has been reached; before seed drying to assess the drying needs of a lot (drier settings); before and during storage; and at final packaging.

A seed producer aims to reduce seed moisture content to the official standard and no further. Drying is expensive and any unnecessary loss in seed weight is an additional loss in revenue. Seed moisture content testing, therefore, is a vital step in official seed quality assessment. Standards should be set that strike a balance between the attainable moisture content, taking into account the relative humidity of the air in the seed production and conditioning areas, and the preferred seed moisture content from a seed quality point of view (bearing in mind the storage conditions). An example of seed moisture standards is presented in Table 3.8.

Seed moisture content can be measured on a wet weight or a dry weight basis. That used in seed testing is on a wet weight basis, i.e. the amount of water per gram of seed, expressed as a percentage.

A sample presented for moisture analysis has to be packed in a moisture-proof container from which most of the air has been removed. The time between sampling and testing, and the sample's exposure to the atmosphere during testing, should be kept to a minimum.

Standardised seed moisture tests (ISTA) are done by drying the sample in an oven after the sample has been.
weighed. The weight lost after a prescribed period of drying at a prescribed temperature will give a reproducible MC measurement.

Large seeds have to be ground (most cereals, legumes and cucurbits), moist seeds have to be pre-dried, and oil seeds have to be dried at a lower temperature (103°C) and for a longer period (17 h) compared with other seeds (130-135°C for 1–2 h, depending on the crop).

Methods for each crop have been well documented (ISTA, 1993).

<table>
<thead>
<tr>
<th>Crop</th>
<th>MC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>12</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12</td>
</tr>
<tr>
<td>Millet</td>
<td>12</td>
</tr>
<tr>
<td>Rice</td>
<td>13</td>
</tr>
<tr>
<td>Bean</td>
<td>12</td>
</tr>
<tr>
<td>Groundnut</td>
<td>9</td>
</tr>
<tr>
<td>Soya Bean</td>
<td>11</td>
</tr>
<tr>
<td>Sunflower</td>
<td>9</td>
</tr>
<tr>
<td>Tomato</td>
<td>9</td>
</tr>
<tr>
<td>Cucumber</td>
<td>9</td>
</tr>
<tr>
<td>Radish</td>
<td>7</td>
</tr>
<tr>
<td>Okra</td>
<td>11</td>
</tr>
</tbody>
</table>

**Table 3.8 Examples of standards for seed moisture content (MC)**

**Purity analysis**

A farmer expects to buy pure crop seed free of weed seeds, chaff, stones or other extraneous matter. It is impossible to remove all unwanted material but purity analysis, combined with standards for maximum impurities, should increase confidence in the seed offered for sale. Purity analysis determines the percentage of pure seed by weight and identifies the composition of any impurities, especially with regard to weed seeds. For uniform reporting and identification, a seed laboratory should maintain a collection of weed and crop seeds and have a copy of ISTA’s (1983) published list of plant names. The analysis is done on a defined quantity of seed (ISTA, 1993) spread on an especially designed table (sometimes with an opaque glass top and lighting from below i.e. a diaphanoscope). The analyst separates the following components:

- **Pure seed**, including any seed fragments that are larger than half the size of a whole seed. Sometimes, other varieties can be identified in the pure seed fraction in which cases they are reported separately.
- **Other seeds**, including those of other crops and weed seeds. The identity of any such fraction must be reported.
- **Inert matter**, including any other material and including seed fragments that are less than half-seed size.

There are specific rules for some crops. For example, a groundnut seed of which part of the seed coat is missing is classified as inert matter despite the fact that more than half of the seed is present. Clearly, empty seeds of various crops also belong to the inert matter fraction.

The fractions are weighed separately, normally to a precision level of 1 or 0.1 mg and duplicate analyses also have to comply with maximum tolerances.

**Germination tests**

Germination of a seed depends, amongst other factors, on moisture availability, light and temperature. To standardise the evaluation of seed lots in different seed laboratories, ISTA (1993) describes precise testing conditions and methodologies for each crop. Germination tests are carried out on the pure seed fraction derived from the purity analysis. For most crops, 400 seeds per 4–8 replications are placed on or in the correct substrate (e.g. sand, paper). To avoid substrate contamination of the germinating seeds, paper has to be non-toxic and sand has to be of the right texture, germ-free and non toxic. Approved blotting paper often has to be imported. This is expensive. Sand can best be obtained from rivers or lakes; the permanently submerged condition being the best guarantee of absence of harmful pathogens. It has to be dried, sieved and properly mixed to create a uniform substrate.

Sufficient water is added to the substrate, the seeds are spaced evenly at a constant depth and the whole is subjected to prescribed temperature and light conditions. Germination cabinets or walk-in germination rooms with automatic temperature and light control should be used to obtain constant germination conditions. Such equipment is rather expensive to install and to maintain. Any local adaptation must be done with the greatest care. Most regional laboratories in Indonesia use locally made germinators which simply increase the humidity of the air. The ambient temperatures there, are acceptable for germination of the most commonly tested seed (rice) although the repeatability of such tests may be lower than when performed in a fully controlled environment.

Evaluation of a germination test involves counting both the germinated and the remaining dead or dormant seeds in the substrate. Germination is described as ‘emergence and development from the seed embryo of those essential structures which, for the kind of seed being tested, indicate the ability to develop into a normal plant under favourable conditions in the soil’. Evaluation of a germination test requires expertise in identifying these structures. Seedlings may be normal or abnormal, depending on the balanced development of shoot and root organs (different for different groups of seed, e.g. hypogeous versus epigeal germination). Abnormal seedlings can be damaged (seedlings with an essential structure missing or badly damaged) deformed or unbalanced (due to physiological disturbances) or decayed (due to a primary disease infection).

The results from the replicates have to be averaged, but the differences should not exceed prescribed permitted levels (ISTA, 1993). The average germination percentage is reported and compared with the national standards.
Examples of such standards are given in Table 3.9. From this table it can be seen that the economic importance of a crop plays a role in seed standards. The standard for rice is higher in Sri Lanka than in Zambia where its importance to agriculture is less. The opposite applies in the case of maize in those two countries.

Table 3.9 Certified Seed standards for various crops in use in different countries

<table>
<thead>
<tr>
<th>Crop</th>
<th>Germination</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Taiwan</td>
<td>Zambia</td>
<td></td>
</tr>
<tr>
<td>Leek</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onion</td>
<td>75</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Cabbage(s)</td>
<td>75</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watermelon (seedless)</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Okra</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>75</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>85</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>75</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Common Bean</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Cowpea</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Gram</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundnut</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Soya Bean</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Finger Millet</td>
<td>75</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

Viability tests
A germination test provides information on the ability of the seeds in a seed lot to germinate at a particular time. For most seeds, this germination percentage will only decline with time; for others, however, the germination potential (viability) is higher (due to dormancy) than that recorded by a germination test. The value of the seed lot, therefore, can be over- or under-estimated.

Standard dormancy-breaking methods can be implemented if dormancy is suspected (ISTA, 1985). These differ for different crops and include cold treatment, soaking in potassium nitrate, pre-washing of seed, dry storage and Gibberellic acid treatment. For hard-coated seeds such as several fodder legumes (e.g. Centrosema pubescens) and for hard seeds of normally non-dormant seeds such as okra and bean, scarification (mechanical or chemical) or hot-water treatments can be applied. Dormancy has been described at length by Khan (1982), Bradbeer (1989), Hilhorst (1990), Simpson (1990) and Derkx (1993).

Another method of assessing viability is by use of the Tetrazolium test. This involves soaking the seed in a buffered solution of triphenyl-tetrazolium chloride, which stains living tissues red. The staining pattern can be used by experienced laboratory staff to predict the capacity of the seed to produce a normal seedling. With the exception of ornamentals, trees, shrubs and palms, this method cannot be used to replace a germination test for official purposes. Often, Tetrazolium tests are used to get an idea, quickly, of the seed quality; if, for example contract growers have to be paid for their seed.
Vigour tests

Another shortcoming of the standard germination test is that it gives little information about seedling vigour and the expected germination and vigour after prolonged storage of the particular seed. The standard germination tests are done under optimum conditions in order to standardise the methods.

Because of various stresses, field emergence can be considerably less than expected from an ISTA laboratory germination test. Seed vigour, or 'germination energy' as it was initially called, 'comprises those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions' (AOSA, 1983).

Seed vigour is affected by the genetic constitution, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, weight and density, mechanical integrity, deterioration, ageing and pathogens. The relationship between viability and vigour is presented in Fig. 3.11.

![Graph showing relationship between seed vigour, viability (germination) and deterioration, and the area of application of vigour tests.](image)

The X and Y points on the viability and the vigour curves illustrate the increasing 'gap' with increasing deterioration between the ability to germinate and vigour (From AOSA Seed Vigor Handbook, 1983)

Vigour tests seek to quantify the expected reaction of a seed lot to the various stresses in the field. The most common are:

- **Seedling growth rate test** - a rather standard germination test, but with more precise observations on the moment of germination, the rate of seedling growth and a detailed assessment of morphological deficiencies.

- **Stress tests**. These include the accelerated ageing test, the controlled deterioration test, the cold test and the cool test. Accelerated ageing is done under conditions of high relative humidity and high temperature (40-45°C) for 2-4 days; thereafter a standard germination test is performed. This gives information about the general level of seed deterioration, and thus, on stress tolerance and longevity in storage. The cool test of maize imitates field conditions in early spring at higher latitudes; it involves incubation at 10°C. The cool germination test for cotton seed at 18°C gives a measure of general stress tolerance because the temperature is close to the absolute minimum germination temperature for the crop.

- **Biochemical tests** - such as the conductivity test and the Tetrazolium test. The conductivity test measures cell membrane degeneration by measuring the electrolyte leakage from the seeds. The Tetrazolium test, which is basically a viability test, can also be used as a vigour test when a very precise evaluation of the colouring patterns and intensities is done.

Vigour tests such as the above (especially the accelerated ageing test) can be used for fairly accurate prediction of the storage potential of each individual seed lot. This information can be used to improve the efficiency of seed store management. Computerised models, whereby the effects of storage conditions for each individual seed lot can be estimated, are now available for a number of crops (Kraak, 1993).

Seed health testing

Seeds can be carriers of seed-borne pathogens such as viruses, mycoplasmas, bacteria, fungi and nematodes. Some of these are seed transmitted, i.e. the seed-borne disease can indeed affect the germinating seed or the resultant plant. Cultural methods, aimed at minimising the risk of infection, and seed treatments may be applied to cure an infection (Ortega, 1990).

Seed health testing can check on the effects of these measures and can be especially useful in preventing the introduction of new pathogens into an area. Because of this, such tests can supply an important measure of overall seed quality. The health testing methods should be simple, cheap, quick, and reproducible, and should facilitate identification of the pathogen. Visual assessment can identify sclerotia of *Sclerotinia* spp. Spots on beans, resulting from an infection with anthracnose (*Colletotrichum lindemuthianum*) or *Ascochyta* sp., can be identified (sometimes UV light is required for this). In celery, septoria can be identified by staining celery seed with Cotton Blue. More advanced seed health testing methods include:

- **Blotter method** - the incubation of seed on blotting paper. Seed-borne pathogens can be identified and the severity of infection assessed on the basis of vegetative growth rate, emergence of fruiting bodies and symptoms on seedlings.
• **Agar test** - incubation of seed on a sterile medium; either a general agar or media that specifically promote the growth of certain pathogens.

• **Serological techniques**, based on the interaction of antigens and antibodies, are very specific tests for particular virus diseases.

• **Grow-out tests** to observe symptoms on the seedling.

Details of seed pathology and seed health testing are presented by Neergaard (1977), Mathur & Joergensen (1990) and Dickmann (1993). ISTA produced a handbook on Seed Health Testing: *An Annotated list of Seed Borne Diseases* (Richardson, 1981) and working sheets dealing with individual pathogens (Joergensen, 1981—).

**Post control**

In post control, samples of seed lots are planted in trial fields once field inspection and laboratory tests have been completed. The main objectives are:

• to check the varietal identity of seed lots;

• to check the effectiveness of the field inspection (varential uniformity);

• to trace changes in identity of a variety during the seed production cycles and maintenance selection;

• to check the performance of the seed laboratories; and

• to check the validity of complaints from users.

Post control of Certified Seed is generally done during the same season that the farmers plant the seed. Therefore, it is not part of the certification process (it cannot stop the release of a seed lot) but its main purpose is to check the certification system. When higher generation seed lots are checked in the post control system, however, it also acts as a pre-control on the production of lower class seed. The results can be used to advise seed inspectors on which particular lower class seed production fields to concentrate.

Considerations for post-control field layout:

• all samples of a particular variety should be planted next to each other;

• reference samples should be planted alongside every variety;

• different varieties (of the same crop) with similar characteristics should be planted next to each other;

• to save resources, land can be reserved in the post control fields for DUS-testing of proposed new varieties (see Chapter 5); and

• planning of a trial has to be done in such a way that optimal cultural practices can be carried out to safeguard the full expression of all characteristics. The occurrence of volunteer plants and the build-up of diseases and pests from previous crops have to be prevented.

**Varential uniformity**

For a judgement of the varietal uniformity, many plants are required in each post control trial. In general, field planning will be the limiting factor when the number of samples to be tested is decided. According to the OECD guidelines, a sample size of $4n$ (where $n$ = expected number of off-types) is considered to be sufficient. This means that when the expected number of off-types is 1 in 100 (according to the field inspection of a particular lot), the post control plot should contain at least 400 plants. When the number of plants (and plot size) is smaller, there is a greater risk of an incorrect off-type count.

Because of the required sample size, only a limited number of samples can be tested in the post control field. Accurate confirmation of the field inspection results, therefore, is not possible. However, gross failures of the field inspection or serious admixture of grain into the seed by the seed grower can be recognised in limited-sized plots.

**Observations**

Observations to check on the identity and uniformity of the plots should be made at all stages of plant growth. Where the development of the plants is found to be irregular due to external factors, care should be taken not to misjudge the small underdeveloped plants as off-types.

Off-type counts can be compared with the field inspection results or the field standards, using statistical techniques. The accuracy of the count depends on the sample size (number of plants in the post control plot). A guideline is given in Table 3.10.

This table can be used as follows: The post control section may want to check a field inspectorate off-type count of 1% in a plot of 100 plants, only one off-type plant is expected. Due to the statistics of random sampling, however, the field inspection result can be declared incorrect.
only when four or more off-types are found. Where a larger plot is involved (1000 plants), the expected number is 10 and action can be taken against the field inspector (and the seed lot) when 13 or more off-types are found. The test, using the larger plot, therefore, is significantly more precise. It is clear, then, that the post control facilities are the limiting factor: wheat can be checked more easily and accurately than can maize because 1000 wheat plants require less space than do 1000 maize plants.

**Organisation of seed quality control**

Seed quality control has to be checked in order to ensure that the seed producer knows the quality of each lot, i.e. to protect his reputation and his future market (company interest) and to ensure that substandard seed does not reach the market (farmers’ and national interest).

**Internal quality control**

Seed producers try to make sure that only seed of acceptable quality is sold. The entire seed production planning process has to take this requirement into account. Seed quality has to be borne in mind when the production area and individual contract growers are chosen, production fields are inspected and agronomic recommendations are made to a grower. Testing of harvested seed before processing (farm stock approval testing, intake sampling and testing) and after processing (e.g. before blending, during storage) are further checks on quality. These activities are independent of all the official seed quality control activities.

Contract growers are selected on the basis of their past performance, their knowledge and reliability, and on their resources (access to land, tractors, labour, drying cribs for maize, etc.). Past performance as contract growers is judged by the quality of previous deliveries, the record of rejection due to a lack of adherence to the rules (isolation, roguing, general husbandry) and the quantities delivered (reliability). Growers are sometimes tempted to keep back seed when they expect the food grain market to improve in the foreseeable future, or they may dilute the seed with some grain when the seed prices are very profitable. Record keeping is vital, therefore, and choosing growers on the basis of social factors (automatic selection of tribesmates or friends of the production manager) has to be avoided; grower selection can be very effective when representatives of the growers themselves can participate in the selection process.

Seed testing can be done in the field (moisture determination to plan harvesting time), immediately after harvesting (germination, moisture and purity to assess whether the seed will indeed be bought as seed), and upon arrival at the conditioning facility (to assess the amount of pure seed in the bulk and, if the moisture content has to be reduced at the plant, the cost of drying). Since the test results have to be available quickly, Tetrazolium testing can be considered. Purity testing can be done using small-scale processing machines (seed cleaning analysis). This is quick and gives a good estimate of the amount of seed that will remain after processing. The farmers can be paid on the basis of bulk delivered or for the fraction of pure seed with the required moisture content.

Post control of (sub) lots from individual farmers can be very helpful in assessing the performance and reliability of seed growers.

In general, these control activities are executed by employees of the seed producer, either by a specialised internal quality control department or by the contracts-officers and some laboratory staff. There are situations, however, in which (some of) these functions are combined with the official seed quality control activities. In particular, seed processing analysis often can be done best by a central laboratory because of the cost of the equipment. It is important that the staff involved have sufficient work throughout the year. Grower selection and training (before the season), field inspection/advice (throughout the season), and sampling and testing (after harvesting) could be done by the same team.

**Official seed quality control**

The official seed quality control activities are limited to generation control, field and plant inspection, sampling and testing of official seed lots and, possibly, post control. National legislation normally describes the tasks of an official quality control organisation, and international rules determine the methodology to a large extent (OECD seed

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**Table 3.10** Post control standards for off-type counts given below are the 'reject numbers', based on a chi-square (5%) comparison with the field inspection count (reject numbers less than 10 are calculated with a 1% probability, since the plot size is small)

<table>
<thead>
<tr>
<th>Number of plants</th>
<th>0.05</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>Field inspection results (in %)</th>
<th>0</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>5.0</th>
</tr>
</thead>
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<td>100</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>17</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>13</td>
<td>17</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>17</td>
<td>23</td>
<td>29</td>
<td>41</td>
<td>53</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

Source: Courtesy of the Seed Certification Service, Sri Lanka.
rules, ISTA rules for sampling and testing, etc.). Where these international rules facilitate international seed trade, it is important for a country to adhere to them. The effectiveness of a seed quality control service depends largely on its status in the (government) system, its internal organisation structure and its funding.

Official seed quality control should be sufficiently independent of the seed production organisations. In the initial stages of seed industry development, seed quality control often is incorporated in the same (government) seed production unit. This can lead to serious conflict of interests whereby the quality control section can be overruled by the interests of the producer. The end result could be poor seed on the market and a decline in demand. Independence is often guaranteed through national seed legislation.

One of the main issues of internal organisation is the level of decentralisation. Ideally, field inspectors should live in the seed production areas. Field inspection from a central office results in high transport costs and requires good planning of the inspection operation for the various seed production regions, a situation made more difficult because of the weather-dependence of seed production. A disadvantage of decentralised field inspection is that the inspectors are likely to identify themselves too much with the seed growers, which could lead to corruption. Rotation of the inspectors could reduce the problem but the staff may not like to move every three or four years.

Seed testing may also be decentralised, especially in large countries (e.g. Indonesia) and where, because public transport facilities are limited, samples would otherwise have to travel a long way in uncontrolled conditions before reaching the main laboratory. The involvement in decentralising seed testing could be reduced by using locally-adapted methods though they may not adhere exactly to ISTA rules. At least one national laboratory should be able to test samples according to the international rules; it could then also organise a referee testing system for the satellite laboratories to check continually on their performance. Such methods are also used internationally by ISTA to check on the standard of each accredited laboratory. It is important too that the chances for corruption in the laboratory are minimised. An easy method to avoid most problems is to identify all samples by code numbers so that the analysts do not know whose seeds they are testing.

There are two main options for labelling seed lots:

i. company labels that can be used once official approval of the lot has been given in the form of a lot-release form; the label is designed by the company, but carries the logo and name of the certifying agency; or

ii. centralised labelling with official national labels which are attached to the seed bags by officials.

The latter option is much more expensive, especially when the officials have to travel from the central office. Another disadvantage is that the producer may have to delay final storage or dispatch until the official labels are printed. The value of the label is more convincing to the farming community, however, when a standard format is used. Producers could be authorised to print and attach official labels (on the basis of a lot-release form).

Official seed quality control is an expensive operation which, however, is important for the farming community and for national agricultural production. In most tropical countries, quality control is a government affair and investments and running costs are normally paid by the national treasury. Charging seed producers for services rendered is a valid alternative if government budget constraints render a proper operation of the organisation impossible. In an emerging private seed industry, however, the government can stimulate investments by covering the cost of certification and testing for an extended period. As a guideline, the cost of official certification should not exceed 1% of the total seed cost. The budget for internal quality control may cover another 1%.

Charges can be based on planted area, tonnage, or a combination of both, i.e. separate charges for inspection (based on the number of hectares) and testing (based on the number of seed lots and, hence, on tonnage). In determining the charges, it is important to include all running costs and depreciation of buildings, vehicles and equipment (personnel costs may be covered by the government). Income should be allowed to be re-used by an organisation. This avoids the problems normally encountered when organisations are obliged to return revenue to the treasury and run themselves on annual budget allocations. A solution may be to separate, to some extent, the seed quality control organisation from the government and convert it into a foundation, thereby resembling the situation in some industrialised countries. Some European and American seed quality control organisations (e.g. the Dutch NAK), have had a foundation structure since their inception.

The budgetary burden can be reduced through delegation of responsibilities. If inspection of every single seed field at all the important stages of crop development would require too many inspectors and transport facilities, the task of field inspection could be delegated to the seed producer who could combine this activity with the regular field visits of its seed extension staff. The official quality control agency can then inspect a sample of the fields in order to assess whether this internal quality control is effective. A system of financial or other penalties can be designed to promote a more reliable and efficient system of internal quality control (ACE, 1992). Delegation can be done in two ways:

i. officially delegating inspection duties to selected company staff (and using official certification labels; spot checks are made to verify the label); or

ii. delegating the responsibility for seed quality to the seed producer who will attach his own company labels; spot checks are made for monitoring purposes only.
Delegation of responsibilities is used in Brazil’s publicly-funded seed scheme and is promoted by FAO in their quality-declared seed scheme (FAO, 1993). The argument against the second option could be that the control measures are not complete, i.e. that not all seed lots have been sampled and checked by an independent organisation. One should bear in mind, however, that bona fide seed producers will make sure that their brand name is not associated with poor quality seed. Seed quality control started in Europe as a voluntary responsibility of the companies themselves (Serpette, 1990), and only in 1973 did certification become statutory in the United Kingdom (Kelly & Bowering, 1990). In most countries, however, seed quality control typically is considered to be a public responsibility: one which is particularly necessary when monopolies appear in the seed market.

Organisation of seed production
A formal seed chain can be organised in various ways: the objectives, the ownership question and competition are important considerations. Choices relating to these factors can be directed by a national seed policy (Chapter 3).

Objectives
Seed production can be seen, primarily, as a way to increase yields and thus rural incomes and national food security. It can also be regarded as an industry in itself. The difference may seem somewhat academic but it is essential to understand the differences between seed programmes in the tropics and to comprehend the problems that are associated with transition of emphasis from the former objective, to the latter. Seed programmes in the tropics are, in most cases, initiated with emphasis on the first objective; the use of improved varieties should be promoted through the supply of good quality seed of those varieties. This is the basis for government (and donor) activities in this field and the subsidised supply of seed to farmers. In Western countries, however, seed is considered a commodity that should be produced with optimum internal economic efficiency, i.e. proper costing and maximum returns on investment.

The above distinction also affects the internal organisation of the seed enterprise. Non-commercial seed organisations usually are production driven, whereas the truly commercial counterparts are motivated by market forces. The former is aimed at satisfying national and donor policies which can be evaluated best by the quantity of seed produced and distributed. The evaluation of the performance of a commercial seed enterprise concentrates on the returns on investment, i.e. the combined effects of quantity sold and profit margin. Clearly, conversion from the one form of enterprise to the other implies a complete change in the command structure. This is a major problem with which a privatisation process of a public seed enterprise has to deal.

Ownership
Related to the objectives of a seed programme, is the organisation of the formal seed sector. As long as seed supply is considered a service activity for increased yields, government is the most likely operator. Government seed-production units are widespread in the world. The calculated national economic rate of return is high, especially where the first new varieties replace local landraces in high-potential areas. Donors often are involved in such public seed units. In most cases, the internal rate of return of the seed operation is not high because of various kinds of inefficiencies. At this stage, though, that is not the primary concern.

Seed as a commercial commodity requires a different organisation. Governments are not particularly well geared to running commercial enterprises. They are hampered by short-term political goals and by public administration procedures. Commercial seed enterprises can have different organisation and ownership structures:

- Public enterprises - organisations that are not part of the public service but which run on full government investment and may have a government guarantee, i.e. financial losses will be reimbursed every financial year. These can be share-companies with different ministries owning parts of the enterprise.
- Cooperatives, owned by their members who, in this case, are either the seed growers or the farmer-seed users.
- Public/Private joint-venture companies - enterprises run by a limited number of major share-holders. The government is one of the shareholders in many seed sector joint ventures in the tropics and, often, the share composition is fixed such that the government owns either 49% or 51%. This difference is vital, since 51% gives full control, which may be preferred politically (because the national objective will continue to play a role), but which may deter private investment. Public minority share-holding is difficult to accept when one other party is involved (and gaining control). This would mean a tremendous government subsidy to a private party. The most common solution to this problem is the involvement of at least three parties.
- Private seed companies - privately owned companies with preferential, or without publicly traded, shares and in which the owners have either full or limited responsibility. Within this organisational structure an important distinction is made in many (tropical) countries between majority local or foreign shareholding. Also within this group, joint ventures wholly within the private sector are common, often as a cooperation and investment agreement between a local and a foreign partner (e.g. East-West Seed Co., Chapter 7).

For practical purposes, it is important that a seed company can draw on external funds (hard currency), management experience, germplasm and marketing
networks. In a number of cases, multinational companies have an important interest in local seed production. They participate in the seed industry to varying degrees, depending on crops and countries. In Argentina, they control 80% of the maize seed market and almost the whole sorghum seed market, whereas local companies control the wheat seed market (Pray & Ramaswami, 1991). In India and Turkey, on the other hand, investment by multinational seed companies was discouraged vigorously until the mid '80s.

That most multinational seed companies have links with chemical or pharmaceutical industries (Table 3.11), makes them liable to a global public debate. These multinationals could be less interested in disease resistances in order not to compete with their interests in the agrochemical sector: they could aim at package deals that allow them, for example, to sell seed dressed with a patented chemical (Mooney, 1979). Or, as Heisey (1989) puts it, 'Multinationals do not address the needs of the poor'. It is extremely difficult to prove such allegations, however.

Some of the most important (foreign) investors in the international seed trade are: Sandoz, Cargill, Ciba-Geigy, Shell, and ICI. The only multinational that has its roots in the seed business is Pioneer. Third World countries may be afraid to lose control over such an important prerequisite for national food security when powerful multinationals are involved. Where the national market is large enough, a number of multinationals may be expected to work efficiently in competition (Thailand, Argentina); in smaller countries, like Malawi, only one multinational is active (Cargill). In some countries, there is competition between private and public companies (Ethiopia: Ethiopia Seed Enterprise and Pioneer; Zimbabwe: Zimbabwe Seed Co-op and Pioneer). Other countries protect their national public or private seed companies through a number of constructions.

Some major changes have occurred since the publication, in 1991, of the list of Groosman et al. The main ones are the withdrawal of Shell, the rapid rise in the rankings of the horticultural seed companies Takii and Sakata (both Japanese), Ball (after the take-over of Royal Sluis of the Netherlands) and Empresas la Moderna of Mexico after the transfer of Upjohn's interests in the seed sector (Asgrow-Bruijnsma).

**Competition**

The need for competition in order to operate efficiently is a well documented and generally accepted view in western economic theory. The scope and the need for competition is virtually absent when the objectives relate to national food production. In most countries where this is the case, a single national public organisation is generally involved in seed production. In some large federal countries, such as India and Nigeria, each state organises its own production of seed. Some inter-state trade within the country could assure a certain level of competition.

When the objective of internal economic efficiency is the major aim and seed production becomes a business, competition is necessary to protect the farmers.

Monopolies may result in increased prices, reduced attention to quality factors and a reduced level of innovative

**Table 3.11: The largest seed companies in the world (adapted from Groosman et al., 1991)**

<table>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Pioneer</td>
<td>528</td>
<td>Pioneer</td>
<td>735</td>
<td>6.8</td>
<td>Pioneer</td>
<td>1,300</td>
</tr>
<tr>
<td>2</td>
<td>Sandoz</td>
<td>292</td>
<td>Sandoz</td>
<td>605</td>
<td>10.0</td>
<td>Sandoz</td>
<td>760</td>
</tr>
<tr>
<td>3</td>
<td>Dekalb</td>
<td>179</td>
<td>Limagrain</td>
<td>255</td>
<td>9.4</td>
<td>Limagrain</td>
<td>516</td>
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<td>4</td>
<td>Cardo</td>
<td>163</td>
<td>Upjohn</td>
<td>241</td>
<td>11.2</td>
<td>Upjohn</td>
<td>190</td>
</tr>
<tr>
<td>5</td>
<td>Limagrain</td>
<td>160</td>
<td>ICI</td>
<td>225</td>
<td>6.8</td>
<td>Takii</td>
<td>280</td>
</tr>
<tr>
<td>6</td>
<td>Cleveys Luck</td>
<td>144</td>
<td>Cargill</td>
<td>210</td>
<td></td>
<td>Ball</td>
<td>275</td>
</tr>
<tr>
<td>7</td>
<td>Upjohn</td>
<td>139</td>
<td>Dekalb</td>
<td>175</td>
<td>12.5</td>
<td>Cargill</td>
<td>275</td>
</tr>
<tr>
<td>8</td>
<td>Ciba Geigy</td>
<td>119</td>
<td>KWS</td>
<td>160</td>
<td>15.0</td>
<td>Sakata</td>
<td>146</td>
</tr>
<tr>
<td>9</td>
<td>Nickerson</td>
<td>100</td>
<td>Ciba Geigy</td>
<td>150</td>
<td>23.3</td>
<td>Amylum (Orsan)</td>
<td>270</td>
</tr>
<tr>
<td>10</td>
<td>Agrigenetics</td>
<td>100</td>
<td>Cebecco</td>
<td>146</td>
<td></td>
<td>ELM</td>
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<tr>
<td>11</td>
<td>Suikerunie</td>
<td>100</td>
<td>Suikerunie</td>
<td>140</td>
<td></td>
<td>Cebecco</td>
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<td>12</td>
<td>Cargill</td>
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<td>Sanofi</td>
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<td>KWS</td>
<td>247</td>
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<tr>
<td>13</td>
<td>KWS</td>
<td>71</td>
<td>Unilayer</td>
<td>.110</td>
<td></td>
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</tr>
</tbody>
</table>

2: Seed activities of ICI and Suikerunie, viz. Zeneca and VanderHave
4: Estimations based on van Gaasbeek et al., 1994: Ball = Peto, PanAmerican, Burpee, Royal Sluis; ELM=Emrervas La Moderna = Asgrow, Bruijnsma. Vegetable seed activities of Ball and ELM merged into Seminis Vegetable Genetic (turnover US$ 265 mill)

research. When seed production has started as a public activity, it is difficult to introduce competition. Privatisation of the public infrastructure normally results in a national seed company. Entrance into the business is difficult because of the necessary investments in equipment, training and long-term research. Or, in the words of Pray & Ramaswami (1991):

'Owing to the frixity of costs and gestation lags in research, the natural barriers to entering the seed industry may be formidable'.

Competition can be expected, at least for some crops, when international seed companies are allowed to sell their seeds and, especially, when they can be attracted to invest in local seed production. Different international companies competing in the same market may promote the efficiency of supplying seed of a choice of varieties to the local farmers. Seed markets of small countries, however, may not warrant investment by more than one international company, thus the likelihood of competition is reduced. Free trade agreements, such as the Preferential Trade Agreement for Eastern, Central and Southern Africa, could enlarge the market. Also, regional cooperation can be effective for public seed research and production of 'small crop seeds', such as vegetables (Opena & Kyomo, 1990).

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4 Towards integrated seed supply systems

In this chapter, the limitations of the formal seed supply system are discussed. They relate to the different types of farmers and crops and the differences between public and private organisation of the seed industry. Limitations of the local seed supply systems are also discussed but with respect to their flexibility in responding to disasters and to agronomic practices that aim at increased yields. The need to integrate these two complementary seed supply systems, is identified. Examples are given of mechanisms that aim at introducing improved genotypes into local systems, and methods to improve local seed quality. They are dynamic with regard to the level of integration of the local and formal systems and are not necessarily fixed in time and space.

Evaluation of present seed supply systems

Formal seed production: limitations

In discussing general problems of the formal seed sector, a distinction has to be made between public and private operations within the formal seed industry. It is obvious that a full scale public seed industry has problems in sustaining its operations because of a general lack of a business approach and of insufficient (political) will to supply all farmers with all-important crop seeds at a low price. A private seed industry tends to concentrate on profitable crops (high-value, cross-fertilizing crops with low planting rates and, especially, hybrids) and on profitable markets (particularly, the commercial farmers in easily accessible high potential areas).

As summarised by Rowland (1993), when discussing dry-land farming in Africa:

"One recurrent problem in Africa is that commercial seed companies, which tend to be more efficient than parastatal schemes, prefer to operate where good financial returns are likely."

Or, in the words of Echeverria (1990) in a study on maize seed supply in Central America:

"Private (maize seed) companies serve the best endowed areas where the large-scale farmers tend to be located. Multinational companies have greater interest in the more uniform areas where a variety... can be marketed widely."

These are rough generalisations, but they illustrate the basic limitations of seed supply systems. An analysis of the different sectors of the seed chain will give a more detailed picture.

Plant breeding

Scientific plant breeding is a powerful tool to increase the yield potential of crops and adapt them to changing agronomic practices. The resulting uniform varieties respond uniformly to any favourable agronomic practice such as good land preparation, timely planting, application of fertiliser, and controlled irrigation. The uniform varieties, however, also respond uniformly to unfavourable conditions such as a sudden drought or a disease attack. Modern plant breeding, therefore, has been most effective in areas where large tracts of land exist with similar agro-ecological conditions, similar agronomic practices (Chapter 6) and where major sources of heterogeneity can be controlled, e.g. through mechanised land preparation, irrigation and the use of fertilisers.

Results of scientific plant breeding have remained below expectation in areas where the cropping conditions are poor and heterogeneous, as are the farming objectives and practices. The situation prevails because:

- such conditions cannot be addressed by uniform varieties;
- the breeders use the wrong testing environments for their germplasm; or
- breeders are not trained to carefully assess breeding objectives. They work, often unintentionally, with a theoretical crop model aimed at increased yield potential instead of an actual farm situation where actual yields should be improved by taking many non-technical limiting factors into account.

Initially, this lack of success was explained by the ignorance of local farmers who refused to adopt the new technology (1950s and 1960s). Even today this philosophy is still widespread. Phrases like: "The unwillingness of farmers to part with the old seed in exchange for improved seed" (Karie Mervee, 1985) can still be heard. In the 1970s, it was generally agreed that external factors such as insufficient credit and marketing facilities were responsible for non adoption (Greenland, 1975). Even more recently, attention has been given to the concept that the varieties themselves may have some important shortcomings (Chambers, 1983). Also, sensitivity towards the farmer's knowledge is growing (Biggs, 1980; Dupre, 1991; de Boef et al., 1993). New approaches to both priority setting of breeding objectives (Merrill Sands et al., 1990) and actual
breeding methodology (Atlin & Frey, 1989; Ceccarelli et al., 1991) are being developed (Chapter 6).

Three major phenomena are responsible for the poor adaptation of scientifically-bred varieties:

i. Breeders in the formal system necessarily have to work primarily for adaptation to the ecological conditions of the major growing areas of the crop, or for the widest geographic adaptation of the variety (recommendation domain). They do this in order to optimise the research effort (government breeders) or to maximise financial returns on investment (private breeders). Breeding for those farmers who produce primarily for the market can be justified both from the point of view of national food policy and business efficiency. Or, as Haugerud & Collinson (1990) put it: 'Plant breeders cannot respond to every quirk of farmers' circumstances'.

ii. The general lack of contact between the government-employed researchers and the market. Intermediaries, such as the extension service or the seed marketing department often are poorly organised for the specific task of linkage with the breeders.

iii. The arrogance of 'scientists' who claim to be able to solve any problem. Plant breeders should not be designated 'scientists', because they are not employed primarily to develop new scientific concepts (to be published) but to develop new varieties.

There are many examples of breeders' unrealistic perception of the farming reality:

- In Malawi, the introduction of semi-dent (hybrid) maize did not yield the same remarkable result of small farmer acceptance that was obtained in nearby Zimbabwe and Kenya in the 1970s. Once the whole research programme had been realigned to pure flint hybrids in 1987, a ready market was found (Kydd, 1989).
- The introduction in western Asia of stiff straw barley, the stubble of which was unable to be grazed because it cut the lips of the cattle (Ceccarelli, pers. comm.).
- The introduction of short-straw sorghums in areas where the value of the straw for thatching and other purposes is high.
- The introduction of short-maturity sorghums in Zandeland, Zaire, where the extended and more humid storage period could not be bridged (de Schlippe, 1956).
- The introduction of white sorghums in Ghana where the red types are preferred for brewing.
- The introduction of IR8 rice in Asia, which grain type did not correspond with consumer preferences (short grain, not sticky, breakage-sensitive).
- The introduction of more nutritious yellow maize in eastern Africa where white porridge (ugali, posho) is preferred. Stories of diseases and reduced male sexual potency, or even sterility, accompanied the rejection of this maize in favour of the white type.
- The introduction of the CIAT cassava variety CMC 40 in the Dominican Republic, the expectations of which, with regard to yield, were not met under actual farm conditions and whose poor consumption quality caused a very limited adoption rate (Box, 1982).

In general, one can expect a critical attitude with many small farmers towards the uniform varieties that are bred for wide geographic adaptability and a possibly limited adaptation to the specific local conditions. Risk aversion and the diversity of uses of the crop, contribute to such attitudes (Chapter 2).

The above observations would lead to a plea for decentralisation, both with respect to breeding objectives and physical organisation of plant breeding activities. There are limitations, however, to such decentralisation of formal plant breeding.

From an economic point of view, plant breeding is a risky exercise: it requires investment in scientific training and research facilities long before the first results can be expected. In the absence of an operational system governing plant breeders' rights, breeding of non-hybrid varieties generally does not attract private investment. Even in the USA, breeding of self-fertilizing crops is done primarily by public organisations (Jaffee & Srivastava, 1992). The plant variety protection legislation of the USA, which was passed in 1970, seems to have had a positive effect on investment in breeding these crops, but other developments in the same period, such as the increased interest in hybrid wheat breeding, may also have added to this (Pray & Ramaswami, 1991).

A multitude of different varieties, that could fill all ecological and cultural requirements and that are bred by competing breeders, cannot be expected because of the cost of plant breeding programmes. The cost of fully fledged plant breeding programmes for all important crops in a country can be prohibitive for a national government. Choices have to be made continually about which programmes to implement or continue. Productivity of well-funded research programmes is also affected by the official spirit within the system where established names tend to over-rule young scientists with novel ideas. This last problem is not restricted to research in tropical countries and not even to public sector research systems. Rutan (1987) observed that even the IARC's do not escape from such reduced productivity.

Variety maintenance and (Pre-) Basic Seed production

Most national seed companies or seed units depend on Breeder or Foundation seed from the research division of the Ministry of Agriculture. Variety maintenance and Basic Seed production, often, are among the lowest priorities of a national agricultural research system. Rarely are researchers interested in variety maintenance and supervision of basic seed production because it is considered a laborious and routine job with which scientific papers or invitations to conferences cannot be earned. The supply of this vital input in a formal seed programme, therefore, can be a very weak
link in the system, if good arrangements have not been made. These could be prompt payment of a good price for
the seed, or stationing of seed company personnel on the
research farm to ensure that targets are met. Another option
is to allow the seed producers to propagate their own Breeder
Seed (under the supervision of the original breeder).

Seed production planning without a secured timely
supply of good quality Breeder Seed is extremely difficult.

Certified Seed production

Seed production on large government or company run farms
is a very costly exercise. Operation of a contract grower
scheme, however, can also be a weak link in the production
of quality seed because it requires a substantial
organisational capacity.

Even though the development of a good contract-growers scheme may take a lot of time and training, in
most cases, it is the better option compared with large seed
farms. The growers scheme has to be regarded as an asset to
the seed organisation and should be treated as such.

In the operation of a contract grower scheme, a seed
production manager has to balance volume and quality of
seed, and short-term and long-term objectives. The raw seed
price has to be interesting enough for the growers but
should not be too high because this would affect company
performance in a negative way and induce corruption (e.g.
adding grain to the seed).

With vegetable seed production, contract growers pose
fewer problems since, in most cases, plant parts other than
seed are consumed. Competition from household
consumption and the food grain market, therefore, is
reduced.

The production of Certified Seed is anti-cyclic in
relation to grain production. This poses another problem
for the seed production manager. If, in a particular season,
crop yields are poor, grain prices may rise and seed demand
will increase because farmers, encouraged by the
higher prices, will be attracted to plant the crop in the next
season. Large quantities of seed would thus be produced
following poor grain harvests. In seasons with a glut of
seed, the seed production manager may have to be very strict
on quality in order to reduce the quantity of seed delivered.
After poor seasons, on the other hand, seed supply may be
low:

'Failure of a harvest produces high demand during
the next planting season, but the seed project may
also be short of seed for the same reason as the
farmers. This has been a frequent experience in the
Karamoja Seed Scheme.' (Rowland, 1993)

Kimani & Mbata (1993) observed that such
fluctuation in demand is the main reason why local seed
companies in Kenya do not produce pigeon pea seed.

Technical solutions to address this problem include
increased geographical spread of seed production and
maintenance of buffer stocks. Both methods increase the
operating costs. Fluctuations in demand can be overcome,
to some extent, by the supply of hybrid seed because
farmers are likely to buy seed every season, irrespective of
the availability of cheap grain.

Formal seed programmes sometimes have problems
producing seed of a higher sanitary quality than farm-saved
seed, despite the use of fungicides and seed cleaning
equipment. In Rwanda, hand-packing of seed beans appears
to be at least as effective as large-scale seed cleaning (CIAT,
1992a).

Marketing

As presented in Chapter 3, factors influencing the
commercial potential of seeds include the breeding system
of the crop, the level of home consumption and various
crop-specific factors such as viability after storage and
incidence of seed-transmitted diseases.

When seed projects have been initiated as production
driven (public) enterprises, their product mix (i.e. the array
of crop seeds and varieties) rarely is based on market
considerations. Usually, the country's most important food
crop and industrial and export commodities are given
priority (irrespective of their potential seed market and
marketing strategies) and distribution networks for seed of
other crops are under-developed. Verburgt (1982) considered
the distribution system to be the bottleneck of most seed
organisations.

Seed production problems arise rather often, in the
tropics, as a result of insufficient attention to seed pricing.
In government systems, the price is usually fixed as a cost-
plus price. Such a pricing system does not bear any
relation to the market and may be lower or higher than
necessary, depending on the situation. It may be high as a
result of inclusion of depreciation on excessive investment
and the cost of inefficiency. It could also result in an
underestimation of the value of the seed because, for
example, the cost of capital is not included and because cost
factors are based on the previous season's calculations.
The latter is specifically damaging in a high-inflation situation.
The result, then, is insufficient revenue and the continuous
need for fresh injections of capital into the seed system. It
can even happen that the seed price drops below the produce
price as a result of a combination of the above principles
with the normal annual price fluctuations between the
surplus harvesting period and the short supply of grain at
planting. If this does happen, certified (and sometimes
chemically treated) seeds may be consumed. This situation
also arises when seeds are distributed very cheaply as relief
aid (Chapter 6).

National and donor policies aim to have small farmers
in remote areas benefit from 'improved' seed in the same
way that commercial farmers do. A number of problems,
though, make this difficult. For small farmers, the density
of selling points has to be higher, remote areas have to be
covered and the timing of supply is very critical. Packet size
and price are significant. Farmers tend to delay the purchase
of seed until planting is due because factors, such as the
delayed onset of rains, can affect the choice of the variety (as described for different maize hybrids in Zimbabwe by Hangerud & Collinson, 1990) or, even, the choice of crop. Replacing maize with sorghum or pearl millet is a common strategy in cases of drought. Small retailers, therefore, may not want to stock a lot of seed if surplus stock is not refundable (Friis-Hansen, 1992). Also, the seed has to be transported and distributed in a very short period of the year, and timely supply of seed is difficult.

To reach the whole potential market, a range of seed packet sizes has to be available to meet the different requirements of the intended customers. Though buying in quantity should reduce the seed price, when retailers sell small quantities from large bags the situation is open to corruption: for example, food grain may be mixed with the seed, a practice which could destroy the seed company's reputation. When seed is re-packed in smaller units to serve particular markets (a common practice with imported vegetable seed), the re-packer should be careful not to tamper with the seed quality since his name will appear on the retail packet.

The price of commercially-produced seed may be high in relation to the purchasing power of the farmer, or in relation to the price and quality of alternative sources of planting material. This is especially true where production of bulky types of seed (cereals, pulses) is centralised and large transportation costs are incurred. In highly-developed agricultural systems the cost of seed is a negligible proportion of the total production cost of the crop. A study in Peru showed, however, that this is not the case for all crops (Morales et al., 1988): the seed cost of Brassica vegetables was found to be below 1% of the production cost and, of solanaceous vegetables, below 5%. Bean seed, however, required a considerable investment (12%), surpassed only by onion and garlic sets (20% and 29%, respectively).

As mentioned above, heavily-subsidised seed can also have adverse effects. Rowland (1993) observed a negative attitude towards subsidised seed: 'low price seed may be perceived by the farmer as being of low quality'. Moreover, Heisey & Breman (1991) claimed that to speed varietal change, better information for farmers is likely to be preferred to seed subsidies.

A general marketing problem relates to the fact that national markets may be too small to warrant the development of a complete seed system, from research to marketing. This is especially true for the vegetable seed market which is very fragmented. Very few tropical countries can afford to maintain national vegetable breeding programmes for all these crops without commercial export markets for the seed. On the other hand, breeding programmes in the industrialised world do offer considerable advantages in that their advanced varieties often are relatively well adapted to other regions because of the good (and, therefore, rather uniform) crop management for these high-value vegetables. A single country, therefore, could choose to import this seed or, alternatively, regional breeding programmes could be developed in co-operation with neighbouring countries. Such a regional programme is proposed for the countries of the Southern African Development Coordination Conference (SADCC), (DANAGRO, 1988). Another such development is the establishment, in Southeast Asia, of the East West Seed Company, a regional commercial vegetable seed company. The latter covers an area that includes Thailand, the Philippines and Indonesia and has different investors in separate joint ventures. This commercial enterprise, established with private capital from the West, develops a wide range of more or less region-specific vegetable varieties and uses local landraces as an important genetic source for their hybrids and varieties. Such a company would not be easily sustainable in one country only. A national vegetable seed industry is not likely to be viable in any developing country with less than 50 million inhabitants (Grubbem, pers. comm.).

Business management

Often, the internal efficiency of large formal seed systems is low due to various economic and managerial factors. Many government (or government-inherited) management structures are not capable of handling the instant decision making and financial management required of a successful seed business.

A seed unit using contract growers has large capital requirements when the raw seed is bought in, and large capital surpluses during the cropping season after stocks have been sold. Without complete freedom of decision making, manipulation of such volumes of cash is difficult. Where inflation is high, management of large amounts of cash is even more difficult and revolving funds quickly lose value. The situation is aggravated by price controls that do not allow seed prices to cover the effects of inflation. Liberty in pricing the raw seed and the product seems to be essential for a flexible and viable seed production operation. In 1990, seed production in Constantine Province, Algeria, needed a subsidy of US$ 1.5 million for the year (Malki, 1994). Due (1990), in discussing seed industry development in Tanzania, presented an overview of the problems. Some development assistance projects have provided processing plants and Foundation Seed farms of excessive capacity which, together with general over-staffing, seriously affect seed production efficiency.

Corruption (defined as any inappropriate use of resources by abusing the power of one's position within the organisation, including misuses of vehicles, trucks, and labourers for private gain, and taking shares of purchase and building contracts), can be a serious threat to the financial viability of a large seed programme. A seed business offers a wide range of additional options for dishonest personal gain:

- selection of contract growers can be influenced by the farmers if the staff responsible will take bribes;
• acceptance of sub-standard seed lots from growers (a normal mark up for seed of self-fertilizing or open-pollinated crops is 10-20% which, if shared between the farmer and the inspector, can add up very favourably for both);
• purity and moisture checks of intake samples offer great possibilities for small-scale embezzlement; and
• administrative or physical fraudulent increasing of the cleaning loss percentage at the processing facility (and selling the 'rejects') can be very rewarding; increasing the cleaning losses of a 5000 t per year plant by just 1% offers an interesting source of extra income.

If given the chance, creative minds will find many more ways to undercut the performance of a seed production organisation. Where a public seed unit is the only section within a Ministry of Agriculture that handles large amounts of money, pressure to share any extras is sometimes exerted from above, thereby increasing the amounts embezzled.

External limitations

External problems generally relate to national policies on food security and rural development. In many countries, there is pressure to reduce seed prices in order to increase the use of improved seed and increase food production. Such measures result in unrealistically low seed prices that can be very detrimental to government seed production efficiency and to a smooth transition to private sector seed supply.

National policy can also be responsible for introducing strict trade and currency controls which block imports of essential goods such as seed treatment chemicals or packaging materials and can also seriously hamper the involvement of foreign investors (e.g. in joint venture arrangements). One way for an international commercial seed company to avoid locking up investments and profits in non-convertible currency, is to produce three-way crosses of which the single-cross parent has to be imported every year. This gives perfect control over the variety and it secures a steady export of currency.

Too strict quality control and seed legislation systems can also hamper the development of a sustainable seed industry. Jacobs and Gutierrez (1980) blamed the delayed introduction of valuable CIMMYT wheat varieties into Brazil on the country's variety release and certification regulations. National seed certification agencies often regard themselves as a kind of police force with the primary task of rejecting substandard seed in, or on its way to, the market. As soon as the philosophy changes towards one of support for the seed producer in improving the quality of seed on the market, options for a more flexible and viable seed supply situation will arise (Garay et al., 1989).

The extent to which privately owned seed companies are affected by the above-mentioned limitations depends on their size, organisation and level of vertical integration. Those with their own breeding programmes tend to be more independent. For them, the potential width of the geographical adaptation of varieties is important (often an international market is required). They tend to concentrate on hybrids in order to secure a more reliable demand compared with that for open-pollinated varieties. Another important aspect is that commercial seed companies have to supply the effective (commercial) demand, i.e. farmers who can afford to pay the full cost-covering price for the seed.

There may, however, be commercial incentives to include less-profitable crop seeds such as wheat, soya beans and yardlong bean. These include:
• possibly increasing the market for the truly profitable crop seeds by offering the farmers a full range of seed types;
• making more efficient use of the processing equipment by cleaning a bulky crop in the otherwise slack season for the facility; and
• including less-profitable crop seeds in the range of seeds offered, may be expedient for reasons of good public relations, e.g. in order to maintain a good relationship with a national government.

Finally, political interference in domestic seed enterprises (whether public, parastatal or private) can have a significant effect on marketing strategies.

'A typical decision which involves risk is: How much to produce? In a developing country, especially one in which you are the sole source of seed, you must not produce too little. Politically, adequate seed production is a sensitive issue... That's one reason why we choose to over-produce and go to the banker when we have problems financing our inventory of seeds.' (W. Verburgt of the Kenya Seed Company, quoted by Fray & Ramaswami, 1991).

Local seed production: limitations

Selection

Farmers' selection has been very effective in changing plants to meet the vagaries of local ecological conditions and human needs. In many cases, astonishing levels of adaptation are achieved. De Rouw (1991) describes very tall varieties of upland rice in the forest areas of Ivory Coast that are very competitive with the weeds and which fit very well in the labour-constrained farming system. It is a misconception, however, to assume that local varieties are, by definition, optimally adapted to the area and the cultivation practices. In the Masindi District in Uganda, tall rice varieties did not fit the local ecological conditions despite having been grown there for a number of generations in the absence of better germplasm. This rice (with an eight month life cycle) had to be planted mid-way during one rainy season and harvested at the end of the subsequent rainy season, thereby risking drought during the very sensitive flowering period of the crop. Farmers were quick to adopt earlier-maturing varieties when they became available in 1989.
As long as this farmers' selection system depends only on natural ways of increasing genetic variation, such as mutation and casual outcrossing with less-related populations of the crop or weeds, the rate of improvement is slow. During the last century, rapidly-increasing pressures on productivity, that cannot be met easily by such slow adaptations, were caused by increases in human population and land degradation, and significant changes in agronomy (such as the introduction of industrial and export crops, row planted monocultures and market demands for uniform products). External support is required. Also, any introduction of diseases (that are new to the area) as a result of increased trade and research may pose a severe threat to a whole crop if resistant germplasm is not introduced too.

Production

Local seed production has several associated problems.

Despite some often remarkably effective methods of seed selection and production (Chapter 2), technical production problems do arise, especially with seed-transmitted diseases. Often, diseases are not recognised as such. In Uganda, maize cobs infected with common smut were regarded by the people of the Iganga District with wonder and pride. When the disease first appeared, the cobs were displayed at home or staked in the field. *Sthiga* flowers were cut and used in wedding ceremonies and the like when the parasite was first sighted in the Masindi District of Uganda.

Knowledge of whether or not a disease is seed transmitted is often absent, resulting in poor seed production management. In Sri Lanka, it was observed that seed of beans (*Phaseolus*) and tomatoes were collected at the very end of the season, i.e. after the products for the fresh vegetable market had been harvested from the plants and virus and other diseases had ample chance to affect the plant and the seed. George (1989) reported the temptation to sell the good quality melons in the local market and save seed from the off-types or otherwise unmarketable fruits.

Often, there are technical limitations with regard to seed storage. Muhammed et al., (1985) reported that 70% of the farmers in the part of the Kenyan region of Machakos that they studied, use chemical treatment for seed storage. Such chemicals are not available at affordable prices in every country. A considerable number of farmers use ashes or other natural products to protect the various crops (Chapter 2). Storage problems often are responsible for farmers' failure to save seeds of non-traditional crops (Delouche, 1982).

Local seed production cannot be anti-cyclic; seed availability is high after glut seasons, and shortages are usual after poor harvests. When, as happened in the Sahel in the '70s and '80s, extended drought is experienced over large areas, the scarcity of seed poses a considerable problem. A specific example is that of the Machakos District in Kenya where farmers who showed obvious preference for farm-saved seed (Table 4.1) had to resort to other sources after two very dry seasons (Table 4.2).

Severe shortages also happen as a result of civil strife, either because farmers are not able to plant or harvest, or because whole communities are displaced.

These tables show that, in normal seasons, the actual seed source corresponds relatively well with the preferred source (1983 short rains), but that alternative sources are tapped in cases of emergency.

It is not easy for individual farmers to avoid seed shortages after natural or man-made disasters because the farmers have to rely on their crops' internal yield stability under conditions of natural stress. Formal seed sector institutions may produce seed, in areas other than those affected by environmental vagaries, to supply affected areas. Humán & Schmiediche (1991) reported situations in which seed, and even local varieties, were lost because of war.

Local production of certain vegetables and hybrids sometimes is very difficult. Cabbage and onion, for example, are highly appreciated throughout most of the tropics even in areas where the plants seldom, if ever, bolt to flower and produce seeds. Seed production from the few plants that do flower results in selection for early bolting types and, thus, in reduced yield and quality. Formerly, these crops were not cultivated in tropical lowlands close to the Equator. This may be why farmers in these areas grow vegetatively-propagated shallots rather than onions from seed. Nowadays, heat-resistant white cabbage and short-day onions are becoming more readily available.

<table>
<thead>
<tr>
<th>Source</th>
<th>Maize</th>
<th>Sorghum</th>
<th>Bean</th>
<th>Cowpea</th>
<th>Pigeon Pea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>19</td>
<td>10</td>
<td>5</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Own</td>
<td>79</td>
<td>80</td>
<td>88</td>
<td>80</td>
<td>69</td>
</tr>
<tr>
<td>Neighbour</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>Local market</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Food aid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Muhammed et al., 1985.
Table 4.2  Actual seed use during short rains 1983 (A), long rains 1984 (B) and short rains 1984 (C) as a percentage of the farmers growing the crop in the Machakos District, Kenya; one farmer may use more than one source (both B and C seasons were very poor with late onset of the rains)

<table>
<thead>
<tr>
<th>Source</th>
<th>Maize</th>
<th>Sorghum</th>
<th>Bean</th>
<th>Cowpea</th>
<th>Pigeon Pea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Commercial</td>
<td>18</td>
<td>14</td>
<td>68</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Own</td>
<td>78</td>
<td>77</td>
<td>47</td>
<td>70</td>
<td>62</td>
</tr>
<tr>
<td>Neighbour</td>
<td>3</td>
<td>5</td>
<td>17</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Local market</td>
<td>5</td>
<td>8</td>
<td>35</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Food aid</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*: only 20 farmers grew the crop
Source: Muhammed et al., 1985.

Diffusion
Although remarkable geographic diffusion of certain varieties has been reported (Chapter 2), in general, the spread of germplasm is slow, especially where ethnic boundaries are to be crossed (Green, 1987). Often, it is limited to neighbours and relatives. Diffusion of potentially-adapted varieties can be the weakest link in local seed supply systems.

Relative importance of the formal and local seed systems
The use of Certified Seed is significantly below its potential because of the constraints presented above. The African Development Bank estimated that, in Uganda in 1990, approximately 2% of the area planted to the major food crops was formally-produced seed, and Almekinders et al. (1994) estimated that 15-35% of the maize area and 2-15% of the bean area in Central America was planted to seed of the same sector. In Spain in the early ’80s, the use of Certified wheat and barley seed was 14% and 12%, respectively. (Gonzales & Conde, 1985). Turner (1994) reviewed the formal seed supply in India (Fig 4.1). He found that only for some less-important crops (by total seed requirement) was a significant coverage (more than 20%) attained with formally-produced seed. In more developed agricultural production systems, farm-saved seed can have an important place.

DANAGRO (1988) found significant differences between crops and between countries within the SADCC countries. Table 4.3 gives figures (sum of nationally produced and imported Certified Seed) to illustrate these differences. Reportedly, in Botswana the sorghum seeds were delivered free of charge.

Jaffee & Srivastava (1992), estimated the values of farmer-saved and commercial maize seed in a wide range of countries (Table 4.4).

These figures indicate that in all the Third World the commercial maize seed market supplies 68% (in value) of the maize seed. Comparison with Table 4.3 shows that this cannot be translated to area planted to commercial or farm-saved seed. Hybrid seed, generally, is much more expensive than is OP seed and thus it carries more weight in this World Bank study (Table 4.4).
Figure 4.1  Availability of certified and truthfully-labelled seed in India as percentage of total seed requirements (tonnes): 1992-1993. Source: Turner, (1994)

Table 4.3  Use of Certified Seed in SADCC Countries (percentage of total area sown, 1985)

<table>
<thead>
<tr>
<th>Country</th>
<th>Maize</th>
<th>Wheat</th>
<th>Sorghum</th>
<th>Rice</th>
<th>Bean</th>
<th>Groundnut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>15</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Botswana</td>
<td>66</td>
<td>0</td>
<td>100</td>
<td>-</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lesotho</td>
<td>75</td>
<td>38</td>
<td>5</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Malawi</td>
<td>10</td>
<td>19</td>
<td>5</td>
<td>12</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Mozambique</td>
<td>10</td>
<td>13</td>
<td>5</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Swaziland</td>
<td>98</td>
<td>80</td>
<td>21</td>
<td>100</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Tanzania</td>
<td>1</td>
<td>15</td>
<td>9</td>
<td>1</td>
<td>&lt;1</td>
<td>0</td>
</tr>
<tr>
<td>Zambia</td>
<td>70</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>83</td>
<td>97</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Total (1)</td>
<td>49,386</td>
<td>5291</td>
<td>2821</td>
<td>784</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: DANAGRO, 1988
Table 4.4 Maize Seed Values (1985/86)

<table>
<thead>
<tr>
<th>Region/Country</th>
<th>Value of farmer-saved OP seed (US$ mil)</th>
<th>Value of commercial hybrid seed (US$ mil)</th>
<th>Value of commercial seed (US$ mil)</th>
<th>Percentage commercial seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>20.5</td>
<td>5.9</td>
<td>13.0</td>
<td>48</td>
</tr>
<tr>
<td>Argentina</td>
<td>0</td>
<td>0</td>
<td>82.0</td>
<td>100</td>
</tr>
<tr>
<td>Colombia</td>
<td>4.0</td>
<td>0.4</td>
<td>2.5</td>
<td>42</td>
</tr>
<tr>
<td>Brazil</td>
<td>10.0</td>
<td>7.3</td>
<td>115.6</td>
<td>92</td>
</tr>
<tr>
<td>All Latin America</td>
<td>61</td>
<td>19</td>
<td>236</td>
<td>81</td>
</tr>
<tr>
<td>India</td>
<td>21.1</td>
<td>2.4</td>
<td>7.3</td>
<td>31</td>
</tr>
<tr>
<td>Philippines</td>
<td>11.0</td>
<td>6.6</td>
<td>1.8</td>
<td>42</td>
</tr>
<tr>
<td>China</td>
<td>13.3</td>
<td>-</td>
<td>145.0</td>
<td>92</td>
</tr>
<tr>
<td>Indonesia</td>
<td>50.5</td>
<td>1.8</td>
<td>0.8</td>
<td>5</td>
</tr>
<tr>
<td>All Asia</td>
<td>113</td>
<td>9.5</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.7</td>
<td>0.7</td>
<td>7.4</td>
<td>82</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>1.8</td>
<td>0.9</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Egypt</td>
<td>3.3</td>
<td>1.6</td>
<td>0.5</td>
<td>39</td>
</tr>
<tr>
<td>Syria</td>
<td>0</td>
<td>0.2</td>
<td>2.2</td>
<td>100</td>
</tr>
<tr>
<td>All Middle East</td>
<td>6</td>
<td>4</td>
<td>11</td>
<td>71</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>1.1</td>
<td>0.1</td>
<td>12.6</td>
<td>92</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>3.6</td>
<td>1.3</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Tanzania</td>
<td>15.3</td>
<td>1.8</td>
<td>2.0</td>
<td>23</td>
</tr>
<tr>
<td>Nigeria</td>
<td>32.3</td>
<td>7.5</td>
<td>3.0</td>
<td>25</td>
</tr>
<tr>
<td>All Africa</td>
<td>98</td>
<td>22</td>
<td>35</td>
<td>39</td>
</tr>
</tbody>
</table>


Percentages as presented in Table 4.4, can change soon after changes in policy. In Thailand, only 5-8% of the maize area was planted to hybrids in 1988 (Pongroypetch, 1988) and hybrids now represent a major part of the maize area as the result of the promotion of foreign multinational investment in the seed industry. From a survey involving 1452 farmers throughout Sri Lanka, Louwaars (1985) estimated that approximately one third of the farmers who grew vegetables, never bought seed; another third always bought in seed and one third did so sometimes. The formal sector was the main source of seed for 80% of the farmers, irrespective of whether the vegetables were produced for the market or for home consumption. Seed sales, however, were somewhat higher in the more favourable vegetable growing areas of the country. This coverage with Certified Seed is quite high, and can be explained by the low seed price in comparison with the value of the product and, possibly, also because of some bias in the survey, which was organised by the major seed supplier: the Department of Agriculture (which may have influenced a certain level of answers in its own favour).

In Bangladesh, 64% of vegetable seed originates from the informal local seed supply sector and 33% is imported. Only 3% is produced by the local formal seed sector (Santruddin, 1992).

The above examples relate to major food crops and high-value vegetables. It is clear from Table 4.3 that for minor crops, such as secondary food crops, production and use of Certified Seed is much lower, if not absent.

There is a clear distinction between the rate of adoption of Certified Seed and the rate of adoption of modern varieties. Table 4.5 shows the spread of high-yielding rice and wheat varieties in Pakistan between 1965 and 1982. The vast areas planted to improved varieties, however, do not reflect the extent of Certified Seed use (Dalrymple, 1986a: b). Hoisey (1990) estimates that only 8-10% of the wheat farmers in two study areas in Pakistan use Certified Seed for their wheat crop (all varieties). Even new varieties are obtained from formal seed sources in only 32-52% of the cases. Monares (1979) found that 94% of the potato farmers in the Machachi region of Ecuador used improved varieties, while only 3% used Certified Seed.
### Table 4.5  Area planted with high yielding wheat and rice varieties in Pakistan from 1965/66 to 1982/83

<table>
<thead>
<tr>
<th>Crop Year</th>
<th>Wheat HYV</th>
<th>Rice HYV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>area (%)</td>
<td>area (x1000 km²)</td>
</tr>
<tr>
<td>1965-66</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td>1966-67</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1967-68</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>1968-69</td>
<td>24</td>
<td>38</td>
</tr>
<tr>
<td>1969-70</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>1970-71</td>
<td>31</td>
<td>52</td>
</tr>
<tr>
<td>1971-72</td>
<td>33</td>
<td>56</td>
</tr>
<tr>
<td>1972-73</td>
<td>38</td>
<td>56</td>
</tr>
<tr>
<td>1973-74</td>
<td>35</td>
<td>56</td>
</tr>
<tr>
<td>1974-75</td>
<td>37</td>
<td>64</td>
</tr>
<tr>
<td>1975-76</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>1976-77</td>
<td>46</td>
<td>72</td>
</tr>
<tr>
<td>1977-78</td>
<td>47</td>
<td>73</td>
</tr>
<tr>
<td>1978-79</td>
<td>51</td>
<td>76</td>
</tr>
<tr>
<td>1979-80</td>
<td>56</td>
<td>80</td>
</tr>
<tr>
<td>1980-81</td>
<td>57</td>
<td>82</td>
</tr>
<tr>
<td>1981-82</td>
<td>62</td>
<td>85</td>
</tr>
<tr>
<td>1982-83</td>
<td>64</td>
<td>86</td>
</tr>
</tbody>
</table>

Source: adapted from Dalrymple, 1986a; b

Note: in 1982-83 another 42% of the rice area was planted to Basmati, a recognised local cultivar of high consumption quality and grown mainly in Punjab; only in Sind were other varieties important (19%).

### Integrated seed supply systems

Why both the formal and the local seed systems are not always able to produce seed for the whole range of crop and varietal requirements of all the farmers and their (changing) production systems, has been explained above. Richards (1985), who can be considered an outspoken advocate of the appreciation of local knowledge and technologies, summarises this as follows:

'The evidence suggests that smallholder environmental management is dynamic and innovative, and not merely "adapted". This is not to argue that "peasant agriculture" needs no inputs or assistance from the formal research sector, but to point out that a thorough ecological understanding of the aims and methods of small-scale producers is necessary if inputs from scientific research and the development agencies are to complement and augment local trends and interests.'

Or, as Rhoades (1985) explained when considering variety mixtures, staggered planting and local seed bartering systems of potato farmers in eastern Nepal (and the Andes):

'Each practice may be considered "poor technology" if understood outside the context in which they function. The fact that these practices occur independently in widespread world areas in response to similar conditions, suggests that they are rational. To understand them as adaptive, however, does not mean that they cannot be improved upon. Introduced varieties or practices must at least be equally adaptive.'

Only during the last decade are ideas being developed to integrate both seed supply systems, i.e. to combine the most effective components of both systems. From the previous chapters it is obvious that some sectors of the formal seed industry can be very effective in reaching certain groups of farmers with particular crop seeds, whereas informal diffusion can best meet the requirements of other farmers or other crops. It is not possible, therefore, to define 'the integrated seed system' in a manner similar to the formal seed supply system.
Integrated seed supply systems are defined here as systems to supply new varieties and seed to farmers by combining methods from both the formal and the local seed supply systems. There can be many different integrated seed supply systems in space and time, each with different levels of integration, or interfaces between the two systems. The concept of integrated seed supply was introduced by Louwaars (1994a) and elaborated upon by Almekinders et al. (1994) and Louwaars (1994b).

A clear distinction can be made between two types of integration:

i. integrated seed systems that borrow only the scientific plant breeding from the formal system and that use local seed production and diffusion techniques, and

ii. integrated seed systems that aim, primarily, at using seed production techniques of the formal sector for either local or ‘improved’ varieties.

The first type of integrated seed supply systems are linked to technology transfer from research institutions and, therefore, can be called research-based integrated seed supply systems. These use local seed production and diffusion in order to spread the use of new varieties. The second type is aimed, generally, at the development of a local seed industry and, henceforth, will be referred to as ‘integrated systems for seed industry development’. These do not aim specifically at spreading new varieties but at the building of a secured supply of seed to the farmers, often on a relatively small scale. These systems are not static but may grow and become fully-fledged (formal) seed units with time. Caray (1993) considers that only these integrated seed supply systems are valuable for ‘seed system development’. He rejects activities that are only geared to spreading new varieties.

Since the concept of integrated seed supply systems is relatively new, there are as yet very few methods that are fully operational and completely integrated into national agricultural policies. This does not mean, however, that at a local level a certain amount of integration in seed supply is new. The following sections supply examples of methods that are in various stages of development. Because of the wide range of local conditions it will probably never be possible to develop a single method of integrated seed supply that will work in any situation. The concept is based on the assumption that, in every situation, both formal and informal seed supply functions can be integrated into more effective and sustainable assistance for the individual farmer, and agricultural production as a whole. Another corresponding factor is that the development of these systems requires a ‘bottom-up’ approach whereby the direct involvement of farmers, farmer groups or cooperatives, is imperative.

Research-based integrated seed supply systems

Research-based integrated seed supply systems aim, primarily, at the introduction of modern varieties into the local seed production and informal diffusion systems. This type of technology transfer has been an issue of some importance since the beginning of scientific breeding of food crops in the tropics. Various levels of contact between the researchers and the farmers can be identified: the following examples demonstrate an increasing co-operation between the two groups:

- ‘escape’ of varieties from research stations;
- random distribution of samples;
- directed distribution of production kits;
- demonstrations of new varieties;
- sale of seed samples;
- diffusion through on-farm trials; and
- intensified on-farm (client-oriented) research

One way of disseminating a variety, with minimal organised contact between researcher and farmer, is the ‘escape’ of germplasm from research stations. Farmers in the vicinity of agricultural research stations often grow a wide range of unreleased varieties which they obtained from labourers on the stations. A few such varieties have spread through the informal seed diffusion system and become important varieties. ‘Mahsuri’ rice is one example. It was rejected by breeders at a research station in Andhra Pradesh (central India) but the variety reached the farmers around the station and it spread throughout Orissa in the east to Uttar Pradesh in the north (Maurya, 1989). It became one of the major varieties of the country and the researchers had to reconsider their initial reasons for rejecting its release.

Since there was no intentional input from research, this cannot be considered an integrated seed supply system, but it is an illustration of the powerful nature of farmer selection and diffusion.

Diffusion of modern varieties can be done, with very little effort, through the random distribution of samples in the target area. If farmers are sufficiently interested in experimentation, and if the variety meets the local requirements, it is assumed that farmers will continue to grow the variety and distribute it through the informal channels. This method has been tested in Zambia with the bean cultivar ‘Caricca’. In 1986, four hundred families were each given a two kilogram sample of the variety. Grisley and Shamambo (1993) reported that 55% of the farmers participating in a follow-up survey three years later, were still growing Caricca and it was grown by 3.7 times as many farmers as in 1986. Correlations were calculated between various social and economic parameters, and adoption of Caricca beans. The results offer guidelines for future non-random distribution. Variety diffusion in this manner can be very cost-effective compared with the operation of formal seed programmes for non-commercial seed crops like beans in Africa.

The International Rice Research Institute (IRRI) supplies 2 kg samples of varieties for which formal seed supply systems are rare (e.g. floating rice) to anyone who shows particular interest, thereby securing some degree of diffusion before official release.
Sometimes, small quantities of new varieties are distributed to key farmers, together with other farm inputs such as fertiliser and/or pesticides. The purpose is to demonstrate and diffuse new technology (either the variety or the production package), to generate feedback to the extension service and the research system and, in some cases, to increase the future use of Certified Seed. The distribution of these kits is followed by two separate surveys at the end of the season: one to assess the spread of the variety and one to generate the research feedback (Green, 1987). The minikit system has been implemented widely in many countries but Green describes very clear limitations of the system under a poorly-organised and poorly-paid extension system. Often, minikits were given to the same persons every year and some were used by the extension agents for personal gain. Since the performance of the scheme was evaluated by the number of kits distributed and not by the quality of the distribution pattern, any variety for which seed was available could be included in the kits. This frustrated both farmers and extension agents. The method resulted, however, in (further) spread of the rice variety ‘Pokhrelı Masino’ in Nepal (see Chapter 2), and is considered useful in overcoming social, ethnic and geographical barriers in the informal seed diffusion system.

Douglas (1980) reports the successful spread of the rice variety BG 11-11 in Sri Lanka, which resulted in a lower than expected demand for Certified Seed of that variety, probably because seed of the variety spread from the kits.

Variety demonstrations at extension plots or in farmers’ fields can be effective in generating interest in a new variety. Co-operating farmers have to be chosen carefully, taking into account the person’s credibility in the community and the accessibility of his fields. Where new varieties appear to be promising, the proceeds of the demonstration plots tend to find their way to the farming community. That this diffusion starts, in practice, with the co-operating farmer, the extension staff themselves or with their closest friends and relatives, may not hamper the effectiveness of the diffusion itself. Douglas (1980) reports a case of maize demonstrations in which the harvested cobs were sold at double the normal price. Hopefully, the demonstrations did not involve hybrids because, where several maize varieties were included in those trials, the harvested cobs would not represent the tested variety due to cross fertilization.

Dissemination of new varieties can be done, also, through more or less commercial sales of seed samples. In areas of Peru where farmers were too poor to buy seed, small quantities of a new bean variety ‘Gloriabamba’, were given freely on condition that the farmers promised to return the same quantity after harvesting (CIAT, 1990). In this way, the seed returned by the farmer could be used for the next cycle. Within three years, Gloriabamba spread throughout the Cajamarca and to neighbouring provinces, despite having some sub-optimal characteristics. Manshevaile & Bock (1989) reported a similar method, whereby repayment in kind is combined with a guarantee from the project to buy any surplus stock of seed for further diffusion. Church groups, NGO’s and farmers’ associations participated. Sales of small quantities of seed (1-2 kg of beans, i.e. for 100-200 square meters) through village ‘soap and matches’ shops and at weekly markets, is considered an important means of supplying the poorest farmers, in particular, with new varieties. This target group has difficulty in keeping seed on farm, even when home-produced seed and varieties are preferred (Sperling & Loevinsohn, 1993).

Another method of variety diffusion is unguided adoption and diffusion through on-farm trials. Often the harvest from on-farm trials has to be returned to the researcher for measurement. When the harvest of a self-fertilizing variety trial is left with the farmer, he can choose to plant his own selection and, once proven on this slightly larger scale, can disseminate it to neighbours and relatives. Variety release committees, though, may not be too pleased with such strategies (authors’ observation). In a Variety Release Committee meeting in Kawanda, Uganda in 1990, the Department of Agriculture expressed reluctance to disseminate insufficiently-tested varieties which might later prove to be susceptible to diseases and for which the Department then would be held responsible. Nevertheless, Kisakye (1990) reports that this method of germplasm introduction can be very effective for beans. The percentage of co-operating farmers that were still growing at least one of the entries, three years after the on-farm trials, was 100%, 88%, 86%, and 64%, respectively, in the four districts involved: and they had given samples to a total of 174 other farmers. Fifteen of the nineteen varieties in the trials were still being grown, showing the wide range of local preferences and adaptations.

Also, on-farm research co-operators can be used to multiply seed of new varieties with further diffusion being done by co-operators (Baert, 1989).

Diffusion strategies such as the above, can be seriously discouraged as a matter of national seed policy. In Syria, farmers participating in on-farm trials have to return all the experimental planting material to the researchers in order to avoid unreleased germplasm being disseminated in the farming community (Peacock, pers. comm.).

In the above cases farmers were urged to adopt a finished product and, usually, they could choose between their own varieties and one or very few new alternatives. If there is no follow-up survey, the breeder will not get information on why a particular variety is widely accepted and why others are not. Such information is essential for the design of future breeding programmes.

A system of introducing new germplasm has been worked out by the CIAT bean research programme in the Great Lakes region of Central Africa, i.e. Rwanda, Burundi and neighbouring areas of Zaire (Voss, 1987; Sperling, 1992; Sperling et al., 1993). The programme’s approach
was to identify local bean growing experts (most of whom are female farmers), involve them along with the breeders in on-station varietal selection and allow them to further evaluate their own choice of germplasm on their own farms or in communal plots in their villages. The results of this approach are very interesting:

- Farmer-selected germplasm (on station) performed better under their own farming conditions than did material selected by the breeder (Table 4.6).
- Farmers select different germplasm for different plots on their own farm and some made a distinction between the two growing seasons. In other words, they realise the existence of the genotype x environment interaction, which so seriously hampers on-station plant breeding for poor and variable environments (Simmonds, 1991; Ceccarelli et al., 1992). This supports the observation that decentralisation of selection is imperative.
- The breeders gained insight of farmers’ priorities in evaluating germplasm (Table 4.7) which can assist them in their quest for new germplasm and in the design of crossing programmes.

- The programme is not aimed at introducing pure line varieties, but the extensive use of the local methods of varietal experimentation is expected to lead to (physical) inclusion of the introduced germplasm into the existing mixtures, or to the building of new mixtures based on a variety of introduced lines.

This approach would alleviate the pressures to abandon local mixtures in favour of 'modern varieties' and, hence, reduce the pace of genetic erosion in the farmer’s fields. Approximately one third of the 106 bean varieties retained by the farmer-experts co-operating in the programme were found in existing blends and one third in the newly-constructed mixtures composed principally of improved varieties. Sperling (pers. comm.) considers that it is too early to assess whether this method will actually have a major effect on genetic erosion (Chapter 6).

Such combining of formal research with informal selection and diffusion can be very effective with regard to selection efficiency and speed of introduction of new material. Compared with a complete formal seed production and marketing system for seed with no significant commercial demand, it can be cost effective.

### Table 4.6

<table>
<thead>
<tr>
<th>Season</th>
<th>Number of trials</th>
<th>Percentage of trials where new varieties outperformed local mixture (%)</th>
<th>Yield increase of new variety over local mixture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer selection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989A</td>
<td>11</td>
<td>73 ns</td>
<td>3.9 ns</td>
</tr>
<tr>
<td>1989B</td>
<td>19</td>
<td>89 **</td>
<td>33.4 **</td>
</tr>
<tr>
<td>1990A</td>
<td>36</td>
<td>64 ns</td>
<td>12.9 ns</td>
</tr>
<tr>
<td>1990B</td>
<td>18</td>
<td>83 **</td>
<td>38.0 *</td>
</tr>
<tr>
<td>Breeder selection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987A</td>
<td>32</td>
<td>34 ns</td>
<td>- 6.8 ns</td>
</tr>
<tr>
<td>1987B</td>
<td>45</td>
<td>49 ns</td>
<td>- 18.9 ns</td>
</tr>
<tr>
<td>1988A</td>
<td>15</td>
<td>53 ns</td>
<td>0.7 ns</td>
</tr>
</tbody>
</table>

*ns*: not significant; *: *P < 0.05; **: *P < 0.01
A and B are the two seasons during the year.
Source: Sperling *et al.*, 1993
Table 4.7 The most frequently cited positive attributes of bean varieties in on-station breeding trials evaluated by 76 farmers at Rubona, Rwanda, during four seasons, 1988-1990

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Frequency (%) among all varieties (N=1072)</th>
<th>Varieties chosen for home testing (N=198)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High yield</td>
<td>44</td>
<td>68***</td>
</tr>
<tr>
<td>Perform well under bananas</td>
<td>28</td>
<td>41***</td>
</tr>
<tr>
<td>Perform well under adverse conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- on poorer soils</td>
<td>13</td>
<td>29***</td>
</tr>
<tr>
<td>- in heavy rain</td>
<td>32</td>
<td>46 ***</td>
</tr>
<tr>
<td>- in drought</td>
<td>11</td>
<td>12 ns</td>
</tr>
<tr>
<td>Early maturing</td>
<td>23</td>
<td>38 ***</td>
</tr>
<tr>
<td>Good grain colour</td>
<td>13</td>
<td>16 ns</td>
</tr>
</tbody>
</table>

***: frequencies differ at P < .001
ns: not significant

Source: Sperling et al., 1993

There are some preconditions that have to be met:
- A wide range of germplasm, from which the farmers can choose, has to be available without legal restrictions (such as Plant Breeder’s Rights).
- Varietal release regulations have to allow such diffusion.
- Farmers should have ample experience with the crop, i.e. with different varieties under different conditions.
- Researchers should be willing and have the skill to identify local experts and work with them.
- Preferably, the crop should be self-fertilizing and other qualities should be met easily in local production. In this Rwandan case, the disease incidence of the locally-produced seed was not significantly higher (and for some diseases even lower) than seed from the formal sector (CIAT, 1991).

Diffusion surveys threw light on some important limitations of the above methods. Sperling & Loewenson (1993) found that distribution tends to be restricted to a limited number of ‘key-diffusers’ and, normally, diffusion does not start before the third season after introduction. The range of diffusion, generally, was limited to close relatives, best friends and neighbours. This study also showed the importance of on-farm survival of a new introduction: it depends on various socio-economic factors and environmental vagaries, along with a possible lack of appreciation. On-farm mortality of the introduction is high with the poorest farmers who often have to consume their seed. This observation in Rwanda appears to be valid in general. Integrated seed supply schemes, therefore, should avoid concentrating on the poorest farmers when introducing new germplasm and should be aware of the social stratification and its implications for informal diffusion of seed.

Another problem is the laborious recruitment of farmer-experts and the resulting limited range of such programmes. Alternatives, such as representation of women’s groups or local administrative units (parishes, communes) may improve on this but they could reduce the commitment of the collaborators (CIAT, 1992a).

Integrated systems for seed industry development

Where non-genetic seed quality factors are important for crop production, the organisation of seed production may require different methods from those described above. In such situations, the organisations would concentrate either on educating the farmers to improve certain aspects of seed production or on creating a system of specialised seed farmers to supply their respective villages. Alternatively, specialised farmer groups (seed production associations or co-operatives) or small commercial seed enterprises could be formed in an ecologically-favourable area to supply a larger region. Such seed producers could, with time, adopt all the functions of a formal seed sector seed programme. Various approaches to develop such a local seed industry are described below.

Small improvements in local seed production methods can lead to greatly increased seed quality. The methods of collecting poor quality seed from old French bean and tomato plants, in Sri Lanka, was described above. Communicating relatively simple messages to the whole vegetable-growing community can help to improve the
quality of farm-saved seed. Education on plant diseases could further reduce the incidence of seed-borne pathogens. When Trutman and Kayitar (1991) introduced improved disease management techniques to separate seed production plots in farmers' fields in order to reduce disease incidence in bean seed, the response of the farmers was favourable. The researchers anticipated that farmers who adopted the most basic improved seed production techniques would become known as suppliers of better quality seed and, later, could be introduced to more drastic measures such as chemical seed treatment.

Such education could be based on well-illustrated brochures in the local language, combined with a variety of oral extension methods.

Seed-quality improvements can also be attained through the teaching of better storage techniques. The Grain Security Foundation, an USA-based NGO, promotes the use of seed dryers that are constructed with locally available materials, and multi-walled plastic sacks with aluminium lining, to improve grain and seed storage under humid tropical conditions. Loss of viability (due to high moisture content) is reduced and the sacks also reduce the incidence of damage by insects and even storage pathogens (such as Aspergillus and Penicillium) as a result of reduced oxygen levels in the air-tight sacks.

The Winrock-coordinated on-farm seed project in Senegambia concentrates on adaptation of local storage methods to increase the quality of locally-produced groundnut seed (Osborn, 1990).

The results of such improvements in local practices are not always significant. Catling (1992) reports that, in Bangladesh, mechanical grading and hand sorting of deep water rice seed significantly increased the analytical purity of the farm-saved seed, but these measures did not increase yield. Meridlock (1989) noticed that improvement of physiological seed quality is not always the key to improved plant populations and subsequent yields, especially under stress conditions such as are encountered with millet and sorghum cultivation in Botswana. Proper assessment of the seed quality-related factors affecting yield is necessary before actions in this field are undertaken.

An intensified method of improving local seed production is to support the local production of seed by a limited number of key farmers in an area, via the extension service. Such farmers would receive advice on improved seed production techniques such as roguing, disease control and improved seed storage and they would get access to samples of new varieties whenever appropriate. This method depends on these key farmers becoming known in the community as sources of better seed and, subsequently, being able to sell or barter their seed at a premium price. This would, in turn, enable them to further improve on their seed quality through the use of purchased inputs such as seed-dressing chemicals or small seed-cleaning equipment. The method has been used in Nepal, where individuals (USAID Private Producer-Seller project) or groups (ODA-Koshi Hills Agricultural Project) received basic training and seed storage bins at subsidised prices - and 'social recognition' (Bal & Rajdhany, 1987). They also got premium access to fertilisers and pesticides. This set-up appears to work well (Cromwell et al., 1993), but there are doubts about the sustainability of the programme should the premiums be withdrawn. The cash benefit to the seed grower appears to be low. Another problem noted is that the poorest farmers in the region are not reached (directly) with the improved seeds.

In a number of countries, a similar development but with less-intensive official (government or donor) support, was also aimed at in the 'lateral spread systems' which were introduced for cereals. Most of these programmes had relatively little impact, and local seed businesses did not develop; the Philippines was the major exception. There, a large number of seed growers organised themselves into '72 Seed Growers Associations that operate effectively with the support of regional seed testing laboratories.

The impact of this method depends, to a large extent, on the availability of small-scale threshing and cleaning machines (Garay et al., 1992), the efficiency of the extension service (especially with regard to selection of the key farmers) and a long-term commitment of specialised officers to support the programme. In many countries, the extension service is largely ineffective due to financial constraints that result in limited staff mobility and motivation. Another important aspect is the speed of release of new varieties into the system. If non-genetic seed quality factors do not have a major impact on crop productivity, i.e. when local methods produce seed of acceptable physical, physiological and pathological quality, the system depends on a regular supply of new varieties. If the local seed producer does not supply something new on a regular basis, farmers in the community may lose interest and the emerging business will not take off. The productivity of the research system and the agricultural extension organisation (both normally run by government) are often the limiting factors in such schemes. In other areas, legal constraints can oppose the development of such schemes, e.g. the requirement that all seed in the market should be of released varieties and certified and labelled by an official agency. A general problem with such schemes is that they are rather 'top-down', i.e. government officials plan schemes for which farmers may not be waiting.

The appearance of local initiatives to produce seed or to improve the seed quality in the area, may elicit different responses from the authorities. One extreme is that existing infrastructure (often, government units) is protected through strict seed legislation. At the other end of the scale is a balanced support for those sectors of the seed industry that face the greatest barriers to the initial phases of seed industry development. Garay et al. (1989) describe such a development in Bolivia. Analysis of the different sectors of a seed industry resulted in the identification of four major barriers:
i. Seed certification, especially with regard to the organisation and responsibilities of the Certifying Service and the flexibility in seed standards in relation to the quality assurance in the market.

ii. Seed conditioning, requiring large investment in equipment and logistics.

iii. Foundation Seed - a good supply is necessary to avoid degeneration of the varieties through mutation, introgression and mechanical mixing.

iv. The low level of technical education in the field of seed production, conditioning and planning/logistics.

Of particular interest is a programme started with the Soybean Growers Association of Santa Cruz, (Bolivia) and using a new Ministry-owned conditioning plant. Initially, a full certification system was not introduced but field inspection was carried out on off-types and noxious weeds. Standards were set on the basis of optimum quality attainable (depending on the season) rather than maximum preferred quality. The Ministry, with donor assistance, hired and trained staff for conditioning, testing and inspection and the conditioned seed was returned to the seed farmers who, with assistance from a seed-promotion campaign organised by the Chamber of Agriculture, would sell it. Locally-produced seed was found to be superior in quality compared with previously widely-used imported seeds.
Management of the conditioning plant and the operation of the seed-extension and quality-control tasks were reorganised in order to avoid non-competitive government employment regulations, and a fee system was introduced to pay for the services. These activities were coordinated by a Regional Seed Board, and other farmer associations participated. With time, some other crops were included (e.g. wheat) and other regions started seed production of various crops using a similar approach. A major conclusion from this project was that conditioning appeared to be interesting enough for private investment, obviating the need for further government investment in these new schemes. The differences between the regions, with regard to factors such as average land-holding size and the types of crop grown, were reflected in the various organisations of regional seed production - each area established its own Seed Board. These boards finally established a National Seed Board with equal representation of the private and public sectors and of the different regions. A seed law was formulated transferring authority and responsibility to Regional Seed Boards.

The demand for higher quality Foundation Seed increased with the development of the scheme and the experiment stations invested in facilities to ensure a regular supply of the required amounts on a cost-covering basis.

National and regional short courses and study trips were organised to train technicians, extension officers, managers and decision makers. Credit lines, specifically directed to seed producers, were established through the Seed Board with donor assistance. With time, certification under the regional seed boards expanded its mandate with the 'professionalisation' of the seed producers and their organisation. Because of the involvement of all concerned parties in the apex organisation (the Seed Boards), unnecessary legalisation of the seed quality control services was avoided and the importance of its advisory functions was maintained even when an important part of the industry (including generation control, full certification and testing) became part of the formal seed supply system.

This programme removed any barriers to the development of a seed industry. Through support to a pilot scheme, it paved the way for a wide variety of private seed enterprises (see Table 4.8). The following participating institutions are mentioned in the report:

- private entrepreneurs;
- co-operatives;
- agricultural research stations (Foundation Seed business);
- regional development corporations;
- seed-producing agro-industries (brewery, oil seed extraction plant);
- colonies and former settlements;
- NGO's; and
- mixed public-private seed enterprises.

Often, the assistance of international donors was involved.

This wide range of mostly private, small-scale, region-specific and dynamic enterprises is thought to be the best option to reach and supply with seeds, the wide range of farmers in the country.

A number of examples of farmer co-operatives in Latin America that are being used for seed production were presented during a conference at Cali, Colombia (CIAT, 1986). Despite the apparent success in Bolivia, it may be very difficult to copy this approach in any other country and with any other crop.

A similar set-up, for cassava seed (cuttings) in Colombia, received extensive farmer interest in the initial phase but a number of producers abandoned this activity once the new varieties were established, further genetic improvements were not forthcoming and demand for this highly-perishable product appeared to fluctuate with the root price. Only the institutions more directly interested in cassava roots and end products stayed in business. A regular supply of healthy basic seeds (best produced from *in vitro* plantlets) is envisaged to be one of the major prerequisites for the success of commercial cassava seed production (CIAT, 1992b).

This 'bottom-up' approach of integrated systems for seed industry development with well-targeted support from official institutions, seems to have a greater potential than does the 'top-down' approach (regionalisation of formal seed production with assistance from NGO's) described for The Gambia and Ethiopia by Henderson & Singh, (1990).

<table>
<thead>
<tr>
<th>Region</th>
<th>Soybean</th>
<th>Wheat</th>
<th>Corn</th>
<th>Cotton</th>
<th>Rice</th>
<th>Bean</th>
</tr>
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<td>4</td>
<td>11</td>
<td>4</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Gran Chaco</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>0</td>
</tr>
<tr>
<td>Chuquisaca</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>No. of farmers</td>
<td>117</td>
<td>576</td>
<td>13</td>
<td>10</td>
<td>16</td>
<td>19</td>
</tr>
</tbody>
</table>
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5 Seed policy and seed industry development

The impact of national policies on seed systems is discussed in this chapter. Trade policies, specific national seed policies, and seed legislation relating to public and private seed industry development, are covered. In describing privatisation of the seed industry, the authors speculate regarding the effects of such a policy on local and integrated seed supply systems. Plant variety protection is discussed with regard to plant breeders' and farmers' rights, and patent protection. Consideration of the issues raised in this chapter is vital to any understanding of the present seed supply systems in the tropics and is particularly beneficial to those who have some practical experience in this area.

Policy matters

General
The supply of good quality seed is influenced by national policies (see Chapter 3) that fit into the following categories:

- general development policies;
- general business policies; and
- specific policies directed at the seed industry.

National economic and developmental strategies affect the formal seed sector in particular.

The advancement of a seed industry depends, to a very large extent, on how much emphasis is placed on rural development (and agricultural production, in particular) and on the recognition that seed is an effective means of increasing agricultural output. Where no emphasis is given to seed, the local seed supply systems will scarcely change. However, when the important role of seed is acknowledged (including in political circles) government and donor funding is likely to be channelled into the development of a (public) seed enterprise, this, apparently, being the quickest way to tackle the identified problem.

The economic viability of a seed industry and, therefore, the likelihood of private involvement in the seed industry, depends on general business policies such as tax structures, trade and exchange controls, price controls for agricultural inputs and products, and statutory wage rates. Tax relief is considered to be an important factor contributing to the success of the Seed Co-op of Zimbabwe Ltd. (Cromwell et al., 1992). Controlling the price of agricultural produce (e.g. through monopolistic grain marketing boards) in order to keep urban food prices low, can deter investment in agricultural production including the regular purchase of seeds.

Special credit programmes, sometimes linked to the use of improved seed, and intended to alleviate this problem, are rarely effective. The removal of currency controls, however (a measure taken recently by Ghana and Uganda), is an effective way of promoting foreign investment in any productive sector, including the seed industry. In the mid 1980s, the Sri Lankan government lifted its control on vegetable seed imports. This greatly influenced the involvement of a number of parties in the seed trade: timely availability and improved quality were additional consequences. The tendering system by which the government imported seeds, however, ensured that the cheapest subscriber would win the contract, irrespective of the quality delivered. This resulted in considerable negative publicity regarding the use of improved seed in general. Competition in supply will generally improve the quality of the seed in the market.

Further specific policies affect the components of the seed chain in various ways:

- Formal research depends on appropriate funding (normally through national governments or international donor agencies) and on international technical co-operation with other research centres. Both funding and co-operation agreements have to be supported by the national government. Research priorities (and hence efforts to secure funds) depend on food and trade policies. Priority can be given, for example, to food crops or export commodities, to rural food security (e.g. cassava, taro, yams) or to production for urban areas (e.g. rice and wheat). Private research in the field of plant breeding might be encouraged through plant variety protection legislation.

- Rigorous interventions such as the granting of monopolies and subsidies or other specific legislation, can be very effective tools to promote private investment in a specific sector. The Kenya Seed Co. Ltd., in effect, has a monopoly to produce maize seed in Kenya. In Zimbabwe, the use of hybrid maize seed, and thus the market for seed from the formal sector, is promoted by a ban on the sale of open-pollinated maize seed (Friis-Hansen, 1992).

Subsidies can be in the form of a direct cash flow (e.g. to government seed units), donor involvement in
the sector (e.g. to support government units, cooperative or joint venture seed companies), a monopoly on production of public varieties (Zimbabwe), tax- or import duty relief on important investment items (processing machinery e.g. in India), access to cheap credit, or the use of government facilities such as processing plants, input distribution networks or free certification services.

Such interventions are directed specifically at seed industry development which, normally, means formal seed industry development. Other seed supply systems are affected indirectly by such national policies. In general, integrated seed systems are not supported unless the formal seed supply sector has proven to be incapable of supplying sufficient quantities and qualities to the different regions and to the different types of farmers. Local seed systems are likely to be affected by the introduction of uniform varieties and by subsidies on seed from the formal sector.

Seed policy

The policy measures mentioned in the previous section are not controlled by only one Ministry, nor are regulations (for example, on imports and currency control) directed specifically at seed industry development. A national seed policy could be a statement of intent by the government to develop the seed industry in its broadest sense, or to allow and promote others to do so. In practice, though, most seed policies deal with the organisation of a formal seed industry only. Development strategies for integrated seed supply systems, however, could very well be included. Understandably, any national seed policy has to be in accordance with the general economic policy of the country: it can describe, in greater or lesser detail, how macro-economic policies can be used to develop a seed production and supply infrastructure. Whether or not such policies are documented they may aim, for example, at protecting centralised national seed industries from foreign competition (e.g. Kenya) or they may be geared to maximum commercial involvement and competition (Thailand). They may include a strategy to maximise the use of scientifically-bred varieties (Bangladesh) or one to promote the decentralised production and supply of any adapted germplasm (Bolivia). Important issues in many seed policies are the pursued ownership structures of the formal seed sector infrastructure and the ways to arrive at these (Groosman et al., 1991). When such strategies are laid down in writing they may give investors (donor or commercial) the necessary confidence to plan their activities.

National seed policy has to have Cabinet approval but the Ministry of Agriculture should be responsible for its initiation and the definition of the appropriate goals and objectives of the exercise. To avoid conflict with other sectoral- and macro-economic policies, the Minister of Agriculture, ideally, will involve all interested parties through the establishment of a National Seed Committee that includes representatives of the existing (government and private) seed supply infrastructure, the business community (especially the agricultural marketing and input supply sectors), farmers' representatives, legal experts and government officials from various relevant ministries. The primary task of such a National Seed Committee is the drafting of a national seed policy statement. After finalization of the policy document, the committee should retain responsibility for guiding and monitoring the developments in the seed sector: possibly, in the form of a regulatory body for such services with committees for seed certification, variety release and seed standards maintenance.

Included in the policy document should be guidelines for the coordinated development of the whole seed supply chain, from breeding through production, processing and quality control, to distribution and use of seeds. The tasks of different seed supply systems should be spelled out with regard to crops, regions and social stratification of the farming community. Depending on overall national development objectives, seed policy should reflect both concern for small farmer development and support to the development of economic farming. It should fit into the general policies regarding food security and export development and should be realistic with respect to the budgetary constraints of the government. A strong formal seed supply system could be advocated for some major food and industrial crops in high-potential areas whereas integrated systems could be envisaged for other crops in other areas.

A seed policy should describe the ideal situation for supplying seed of the various crops and, taking the present situation as a starting point, it can describe the most appropriate ways to reach such ideals. The policy should offer guidelines on which sectors of the economy should be involved in any future seed sector, and which in the transition period. Important questions that need to be answered are:

- Who will fund these developments?
- Who will execute the changes?
- Who will monitor the progress?

The following categories of information could be included in a seed policy document:

General statements: 'seed is important for agricultural production'; 'seed of some crops appears to have immediate commercial potential, which others may not have in the foreseeable future'.

Objectives: supply of seed should meet the demand in terms of quantity, quality, availability and price, in order to support national food and agricultural export policies.

Description of the envisaged seed sector: with special reference to the level of government involvement (e.g. promotion, certification and monitoring) and the type of actors in the productive sectors of seed supply (parastatals, co-operatives, local companies, joint ventures, foreign multinationals, etc.). There could be major differences in government involvement with
Seed Supply Systems in Developing Countries

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respect to different crops, e.g. major private involvement in the most profitable seed sectors and public responsibilities for the 'small, scattered and risky markets' (Garay, 1993).

**Policy measures:** the measures required to promote the involvement of the above-mentioned actors (e.g. tax measures, price control); measures to be taken to protect farmers' interests (e.g. avoiding monopolies, formal quality control and parallel involvement of alternative seed sources for small farmers); and identification of intermediate steps to be taken to prepare the present infrastructure for change.

**Legal aspects:** the requirements for adaptation of existing legislation to allow the seed sector to develop as envisaged.

**Follow-up**

A seed policy document has to be backed by new legislation that establishes the preconditions for developing the seed industry in the desired direction.

Unfortunately, however, this logical sequence is not always followed. As illustrated in Chapter 3, the development of a government seed infrastructure normally precedes the institution of a seed certification agency which itself requires a legal framework within which to perform its duties. Seed legislation, therefore, is often the result of initiatives of the seed certification agency and tends to concentrate on the regulatory activities of such an agency rather than on promotion of seed production. For example, a common statement in such a law is that all seed in the market (of 'all crops' or of 'cultivars') has to be labelled and/or certified. This rules out any official support to informal seed diffusion systems.

Any seed policy which promotes the involvement of various parties in seed production and supply, therefore, will have to dismantle much of the existing legislation.

**Public/private organisation**

As illustrated in Chapter 4, some serious problems are associated with formal seed production, especially that under government control. In comparison, the private sector has some advantages which may variously affect the different sectors of the industry. Some people in the seed business would go far in their attempts to ban any government involvement. The following lines by Swift (early 18th Century) are often quoted in this context:

'... and he gave it for his opinion, that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind and do more essential services to his country, than the whole race of politicians put together.'

The advantages of a private organisational structure are most pronounced in the marketing and Certified Seed production sectors. Government procedures are not designed to regulate the handling of large quantities of a commodity and they don't have the flexibility required for effective production and marketing decisions. Other functions that could be handled by the private sector, depending on the economic situation and development policies of a country, follow:

**Variety development**

Plant breeding requires a risky and long-term investment. This is an important obstacle for new entrepreneurs entering the business. Public breeding can be defended, therefore, especially for important crops where funding and technical assistance is warranted. Even when private seed companies already have their own breeding programmes, there are reasons for continued support for public activities in this field (Pray & Ramaswami, 1991):

- Private seed companies generally spend less on research (3-5% of seed sales value) than the 'social optimum'. In contrast, Dutch horticultural seed companies spend, on average, more than 10% of their turnover on research and development (Marrinera, 1993).
- Private research concentrates on a few crops and their use by the financially stronger strata of farmers.
- Public research reduces the technological edge that large companies can have over smaller ones, thereby increasing the survival chances of the latter and reducing the risks for new businesses. This results in higher levels of competition in the seed market. Researchers in the public sector can concentrate on fundamental research and develop material for further breeding (e.g. new resistances) or they can produce finished varieties that can be multiplied by any interested seed producer (large or small).

Though public research may be directed towards social equality (e.g. to less-endowed farmers), it can also be regarded as a subsidy to seed companies. Public plant breeding, however, does not only benefit private seedsmen. The competitiveness of a private seed salesman can be enhanced significantly if he can offer a special range of varieties. Business opportunity, therefore, may warrant risky and long-term investment in introducing such a range. The decision would depend on the expected market (importance of the crop, size of the country, expected export market, expectations on popularity of new varieties, possibility of copying the variety and seed replacement factors). An alternative approach for a private seedsmen is to obtain exclusive rights to (produce and) market public varieties. This approach is used in Zimbabwe where the (privately owned) Seed Co-op has the exclusive right to produce public varieties in return for maintaining a security stock of 20% of the estimated annual demand for seed.

A risk associated with the commercial production of public varieties was mentioned in Chapter 4: dependence on government Basic Seed production. When reliable contracts for the supply of Basic Seed cannot be made, private (Pre-
Basic Seed production is justified. This could be done under the government breeder's supervision and a payment of royalties could be made to support the continuation of public research. The issue of public versus private plant breeding, as it relates to the situation in Malawi, was discussed by Kydd (1989; 1990) and Halsey (1990).

Seed production
In most cases, the production of the Certified Seed class(es) can be entrusted to private farmers under contract with a conditioner/wholesaler. Many of the inefficiencies of large government farms can be avoided, thereby. The benefits of increased scale can be effected by contracting with the larger farmers or by group contracting, i.e., a whole village is contracted to produce seed in a single block of land. Scattered distribution of small contract growers increases supervision costs. For the more labour-intensive seed crops, contracts with individual smallholders are recommended (e.g., flower seeds in Kenya, hybrid tomato in Thailand, and groundnut throughout Africa).

Conditioning
Seed conditioning requires a business approach and, ideally, should be done by the private sector. Government involvement can be justified in the initial stages of seed industry development because of the high level of investment and the requirement of hard currency for importing equipment. The Bolivian case mentioned in Chapter 4 is a good example of a policy promoting private involvement in seed supply through government investment in processing equipment.

Marketing
Seed marketing is an activity best done by the private sector. Wholesale, retail and other marketing functions require a flexible business approach with which government units very rarely can compete. Government can, however, support seed marketing through promotional activities (for example, variety demonstrations, establishing a Recommended Variety List, and creating general awareness regarding quality aspects of seed), which can be linked to (or even financed by) the private sector activities in this field. Examples are agricultural shows, 'World Food Day' activities and pamphlets concerning crop production recommendations.

Quality control
Typically, seed quality control is regarded as a government responsibility. Seed quality assurance, however, is also one of the major objectives of every bona fide seed producer who will ensure that all contract growers are well trained to produce optimum quality seed and all staff know to avoid any sub-standard seed lot that enters the distribution system. The seed producer employs staff to supervise growers and test samples. Official government seed inspectors check the same growers and test samples of the same lots. This results in the already-mentioned 'policing' attitude of the official inspectors. Such duplication of activities can be minimised if seed company laboratories are officially licensed to test the samples, and the seed company is made responsible for maintaining the field standards. The official quality control service can then spot-check the various activities and organise a referee testing system to keep the laboratories up to standard. This is similar to the system of 'quality-declared seed', as promoted by FAO (FAO, 1986). It is likely to work only when competition in the seed trade ensures a concomitant business incentive to allow only quality seed on the market. Critics should realise that a number of the major quality control institutions in Europe are organised by the industry itself without much public involvement. Also, it is the private organisations such as International Seed Trade Federation (FIS) and International Seed Testing Association (ISTA) that provide rules and regulations for international trade.

Pray & Ramaswami (1991) raised the following questions with regard to the public/private debate:

- If seed supply is considered a bottleneck, is government seed supply necessary?
- How much privatisation is optimal?
- How would plant variety protection (PVP) improve the amount of technology available to farmers and hence improve their welfare?
- Does restriction of seed imports and foreign seed companies help farmers? Will farmers gain from liberalisation? Will society as a whole gain from liberalisation?

The responsible policy makers and managers are not always able to answer such questions without taking some very practical considerations into account. The actual situation includes certain economically- and politically-sensitive elements.

Often, seed units are initiated with the national welfare in mind. Instead of the internal economic viability of the unit being the major concern when initial investments were made, it was the expected national gain from the extended use of improved seed (and especially of improved varieties). When anticipated increases in agricultural production are offset against the investment in a seed unit, there is little doubt about the justification of the (often donor-aided) project. With time, however, the internal economic efficiency of the project receives more attention, especially when donors with a 'free-market bias' are involved. An additional practical problem is that donor-assisted projects have a limited lifespan. That most projects have a certain amount of locally-contributed finance can be regarded as a necessary sacrifice on the part of the national budget to gain access to foreign currency. When the external funding ceases, the need for local funding increases in order to continue the project. However, the macro-economic benefit from supplying these local funds has gone, together with the donor support. For this reason it is advisable to emphasise internal economic efficiency in seed projects.
National governments often are concerned about the kind of private sector involvement to allow or promote. Very rarely is seed production seen by the local business community as an ideal sector for investment because of the long-term strategy required. Greater (short-term) profit is expected from, for example, the importation of luxury goods or food stuffs. Even though a government would like to envisage a healthy seed industry with competition, it is not easy to attract a lot of local commercial investors. On the other hand, foreign investment in the production and marketing of the seeds of major food crops is not popular in some cases, because of the fear of dependence. A good example is that of international trade in hybrid maize seed; countries may depend on annual imports of parent material or commercial seed. The unpopularity of this has been fed by the merging, during the past few decades, of major seed companies with (agro)chemical and other major industries. There is a growing concern that this integration could lead to reduced international competition and a greater dependence on biotechnological inventions and agrochemicals. It is those multinational seed companies that can afford to make the necessary investments in variety development, however, that can increase the production potential of the national food crops.

Thailand has opened its borders to multinational seed companies that compete in the maize seed market. Kenya remains closed and depends on its own research (which made considerable progress in maize hybrid development in the ’60s and ’70s). Other countries may be too small to expect all major international companies to invest and compete.

Even where a national government agrees that certain aspects of the seed industry should be the responsibility of the private sector, transferring the existing public infrastructure into private hands can be a very difficult process. Government may have to sell equipment, close government seed farms, lay off staff and change job descriptions (and actual staffing) at various levels of the organisation (as happened in Sri Lanka and Bangladesh). These activities appear to be not very different from a major re-organisation of a large enterprise, but the nature of the government organisation poses very specific additional problems. Selling of equipment (often donated and rarely properly depreciated) is likely to involve corruption. Closing down seed farms and laying off large numbers of staff will likely put politicians in a position where they fear for their own jobs, particularly if their constituency is affected. Senior government servants are not likely to step aside readily for commercial managers and vice versa.

The result of all this is that public servants at various levels will try to slow down the process: general government regulations offer ample opportunity for this.

Commercialisation of government seed units can be done in one of four ways:

i. Slacken government procedures to allow the public unit to act more like a private company, e.g. allow unit to operate a revolving fund, hire and fire staff, etc.

ii. Convert the government infrastructure into a private company, initially with government share-holding, thereby allowing the management full liberty in commercial decision making and limiting subsidies. This action is intended to attract commercial investment in due course.

iii. Privatise the infrastructure in a joint venture arrangement with a private party.

iv. Promote private investment in competition with the existing government infrastructure.

The first option is the most conservative and, generally, results in an increased production of seed but not necessarily in reduced business losses. The influence of politics on decision making and on financial matters, especially, often remains counter-productive. The same applies in parastatal company structures which tend to become politicised and inflexible with time. Only when commercial managers are hired with complete freedom to make decisions and direct personal (financial) interest in the performance of the company, may this option work as an intermediate between full government control and a private business.

Joint ventures can work very well. At the outset, they need to have clear short- or medium-term profit prospects, however; this is often not the case in public institutions. Also, the government is likely to be concerned about losing control (having less than 51% of the shares), while private investors may be hesitant to put their money into a government-controlled company.

A joint venture with a development institution can be a way of overcoming some of the above problems. The Zambia Seed Company (ZAMSEED) was converted into a joint venture with a Swedish commercial seed company with the assistance of Swedish development assistance funds. To reduce political influence, the Zambian government shares were handed to the state mining company. Despite long-term Swedish involvement, ZAMSEED has not become a highly profitable venture with commercial investors eager to invest therein. In the case of the National Seed Company of Malawi, a joint venture arrangement was made with a British semi-commercial development agency (CDC) which brought in foreign management; the US-based multinational, Cargill, took over responsibilities to run it as a fully commercial enterprise (Chapter 7).

Promotion of private investment in seed production while continuing to support the public seed production infrastructure, is not an easy option. The private investors need to be assured that the public competitor will not be supported by subsidies and other regulations beyond acceptable levels. Foreign companies can, for example, be seriously blocked by variety release procedures that promote home-bred varieties. On the other hand, open competition will, almost without exception, result in the disappearance of the public company from the most profitable markets. This may aggravate the financial performance of the public
company which remains responsible for supplying remote areas and less-profitable crops, activities that were previously cross-subsidised by the more profitable regions and crops. This approach was chosen in Thailand where the public seed units have been losing a relatively profitable OP-maize market to commercial hybrid seed competitors from foreign investors. In India, the public infrastructure successfully confined itself to Basic Seed production to supply the emerging small- and medium-scale local seed businesses. This option, which is based on the American experience of public breeding and Foundation Seed production at Universities, is an interesting case. It may not be applicable, however, in smaller countries (especially in Africa and Central America) where there are insufficient business opportunities to allow a large number of seed companies to compete.

When evaluating national seed supply systems and seed policies, it is very important to check that relevant decisions were made in the light of local situations. Seed industry development in many developing countries has taken a rather different course compared with the evolution of seed industries in industrialised countries. A major difference is the involvement of donors. Douglas (1980) describes a 'natural' development whereby different stages of seed industry development can be identified, based on the level of development of a hierarchical set of activities. This is interesting as a mental exercise but is unrealistic in practice. A country may have an active seed legislation (stage 4) as the result of (over-) active donor involvement, whereas the breeding activity may be only at the first stage, i.e. limited to testing of introductions only (Douglas, 1980); and countries may be in an advanced stage of development for maize seed supply but have no system for other important crops, such as cassava.

After their development in the '60s, notably in India, such seed industry development 'blue prints' dominated donor assistance in this field throughout the '70s and most of the '80s. They are at the base of many current problems in the formal seed industry (Chapter 4). Grobman (1991) claims that there is now a 'model for action in restructuring the national seed systems in developing countries' that is based on experiences in Turkey. This may lead to another 'blueprint' for seed industry development: one for a worldwide privatisation of the industry. Although valuable in a number cases, it cannot be applied universally because of a too general perception and its disregard of nation-specific problems.

Legislation

Seed legislation

Bombin-Bombin (1980) presented the results of a survey of seed laws throughout the world. This section is based largely on that study. The purpose of seed legislation is to facilitate and regulate the production and trade of quality seed. Normally, Seed Acts are independent of related laws on phytosanitary control and plant variety protection though they often mention these in order to make the appropriate connection. Kenya, Chile and Argentina are exceptions inasmuch as their seed laws do include plant variety protection.

A Seed Law results from the formalization of a general policy on seed supply. Typically, it starts with a general policy statement of the objective followed by: definitions; a description of an institutional framework with the basic tasks; responsibilities and authorities of its components; basic methods of law enforcement; and the definition of contraventions and concomitant penalties. The Seed Act itself may be a very short document. Details of related elements (for example, the variety release and certification processes) are laid down in regulations which do not have to be passed by as many legislative bodies as does the Act. It is advisable not to include too many specific rules in the mainframe of the law because the regulation of agricultural production in general, and seed supply in particular, requires a flexible approach. Very often, seed legislation in developing countries is based on seed laws of the West. Those of Britain and Spain, especially, have served (too) readily as models for local legislators.

Policy / objective statute

The opening paragraphs of a Seed Law normally include a statement regarding the value of supplying quality seed for agricultural production. In stating the objective of the law, some countries emphasise promotional intentions, e.g. Spain: 'The desire to stimulate the production of high quality seed and to encourage its use by farmers ...' Most legislators, though, concentrate on the regulatory processes, e.g. India: 'to provide for regulating the quality of certain seeds for sale, and for matters connected therewith'; and Chile: 'Decree law ... prescribing rules governing scientific research on, and the production and marketing of, seed'. Legislators of yet other countries, include several objectives, e.g. the proposed statute of Uganda: 'A statute to provide for the promotion, regulation and control of ...' (ACE, 1992).

Definitions

Important definitions are those of 'seed', 'seed class', and 'variety'. Seed can be any seeds, plants and parts of plants intended for plant production generally' (Tunisia) or it can be restricted to particular crops or crop groups for which the law applies (seeds of other crops being exempt from the law), as is the case in India: 'seeds of food crops, including edible oil seeds and seed of fruit and vegetables, cotton seeds, seed of cattle-fodder and jute seed'. In only some countries does 'seed' include seedlings. The 'seed' definition determines the extent to which the law applies: to all seeds; to those of notified crops; to those of notified varieties; or to all certified seeds.

For differences in seed class terminology, see Chapter 3. The most interesting category is that of the last
class i.e. the not-fully-certified kinds of seed (Notified Seed in India, Commercial Seed in Uruguay and Uganda, Prescribed Seed in Zambia). Spain identifies three classes in this category: 'Authorised Seed' (controlled by post control only); 'Tolerated Seed' (only the species guaranteed), and 'Exceptional Seed' (as the name indicates, an emergency seed lot).

'Variety' generally refers to an assemblage of cultivated plants that are distinguishable by common characteristics and retain these characteristics when reproduced. Some laws make special provisions for hybrids and for 'local varieties'.

Institutional framework

Authority, with regard to a Seed Law, is vested in the Minister responsible for Agriculture. The Minister is either advised by, or delegates relevant powers to, a technical committee. These are variously named: the Central Seed Committee (India); the National Seed Committee (Argentina, Chile); the National Seed Industry Authority (Uganda); and the National Seed Board (various countries). There may be separate bodies for variety release and for establishing seed standards, or they may be incorporated in the above-mentioned central organisations. The technical committees are normally charged also with proposing regulations relevant to the Seed Law. General guidelines on representation of the various interested parties in these committees may be given in the main framework of the law.

The relationship between the Seed Law and related legislation has to be spelled out. For example, legislation on phytosanitary control is relevant to that governing seed imports, and plant variety protection is connected with variety registration and eligibility for certification and trade. There should be reference to these (generally) separate laws in order to demarcate responsibilities.

Seed law enforcement

It is important to stipulate which institute(s) is responsible for seed law enforcement (especially variety release, seed quality control and certification), to what extent it can delegate powers (e.g. to internal quality-control systems of companies or co-operatives) and, for each crop, whether or not certification is compulsory. Normally, two sets of data are required in variety release. The variety has to be registered (either through analysis of the breeder's data or through independent grow-out and/or biochemical tests, and the agronomic performance has to be tested under different agro-climatic conditions (VCU-tests). These VCU trials are done by independent (public) bodies, at variety-trial centres, on-farm, or both. In some cases the breeders' data are used.

The legislation provides for one of two systems of variety lists: a Compulsory Variety List or a Recommended Variety List. In the case of a Compulsory List, only seed of released varieties can be marketed. The Recommended List is merely to assist farmers in choosing particular varieties for their specific farming conditions.

With respect to seed quality control, differences of note are those between the systems 'truth in labelling' (USA) and 'minimum standards' (most other countries). In the US system, labels are affixed by the seed producer. Seed of any quality can be sold as long as the print on the label is true. It is possible, for example, to put seed on the market with a 5% germination. The responsibility is on the buyer to check the label and to decide if this seed meets with his requirements. At any point in the marketing chain a seed testing authority can check seed quality in relation to the printed label. In the 'minimum standards' system seed that does not meet the required standards is not allowed onto the market. The presence of a label signifies a certain quality level and responsibility for affixing labels remains that of the certification authority even if this task is delegated to the seed producer. Suggestions regarding intermediate labelling systems are:

- trueness to labelling (whatever is printed on the label should be true);
- trueness to labelling with minimum requirements, e.g. variety name, germination, purity and testing date have to be included;
- trueness to labelling only when seed lots do not meet the minimum standards; and
- minimum standards: seed that does not meet these standards is not allowed on the market.

The first two suggestions involve minimum regulation but may not operate optimally where a large proportion of the farmers are illiterate. Because the last two cases are heavily regulated, they carry the risk of bureaucratic inefficiency negatively affecting the market.

Lists of eligible crops and concomitant minimum standards accompany the law. The basic law is often very specific with regard to labelling and sealing requirements and the regulatory aspects of the law often include registration of persons intending to engage in different aspects of seed production (producers, conditioners, wholesalers, retailers and importers/exporters). This is deemed necessary to perform the basic seed quality control activities. For the same reason, the operation of seed registers often is compulsory.

Some countries operate special credit programmes for seed growers that are registered as seed producers (Morocco). Imports may be regulated with regard to varieties, quality and labelling requirements, e.g. whether or not foreign tests are accepted (from ISTA member laboratories) and labels conform to certain (e.g. OECD) standards.

Offences and penalties

A general statement, to the effect that any act in contravention of the law is considered an offence, is included. General guidelines about the types of penalties can be given. These are normally fines and, in some cases, suspension of registration. The final articles include the methods of jurisdiction and appeals. A few countries have special courts where legal disputes regarding seed laws are handled, e.g. the Seeds and Plants Tribunal, in Kenya.
Regulations
Regulations concerning details of the operation of the committees, the registration procedures and the seed standards need to accompany the law. They have to balance a certain level of rigidity (part of the legal framework) with the maximum flexibility possible, to be able to respond quickly to situations such as sudden shortages due to poor seed yields. Such shortages, in turn, may require facilitated seed imports or temporarily-reduced seed standards.

Side-effects of seed legislation
Seed legislation is deemed necessary to control the formal and, especially, the commercial seed sectors. Farmers have to be protected from purchasing substandard seed (consumer protection) and from planting it (national food security). At the same time, seed legislation and control will protect bona fide seed producers against competition from others who want to invade the market with cheap and low-quality seed.

Most reputable seed producers will not argue against quality-control requirements and procedures (except when operated inefficiently or excessively), although there remains a potential conflict with regard to the speed of variety release procedures.

A side effect of such rules, however, is that they impose barriers on new entrants into the seed business. New initiatives often cannot fulfill all the requirements from the start of the operations and thus are bound to fail if the regulations are to be followed strictly. An example given in Chapter 4 illustrates how limited certification procedures allowed Bolivian farmers to start a co-operative seed business. It appears to be difficult to combine the two main objectives of seed legislation within one law: to stimulate and regulate the production of quality seed.

Existing seed laws can be serious barriers for different integrated seed production initiatives. Diffusion of new varieties from the research stations can be barred because varieties have to be released officially, and schemes to improve and disseminate local varieties can be illegal because the seed cannot be certified. Reinoso & Valdivia (1993) identified this problem in a rural credit programme intended to increase the use of improved potato varieties in Puno, Peru:

"While this legislation is intended to stimulate seed production, in reality it tends to impose a control on the process. No incentives are provided to those individuals or institutions dedicated to seed research, production or commercialization. Rather, the law hinders these processes through excessive bureaucracy and sanctions for those who evade it."

It must be noted that the Peruvian seed legislation is not very restrictive. In fact, a copy of this law was used in Uganda as an example of a rather liberal seed legislation (Grobman, 1991).

Plant variety protection
Plant variety protection laws seek to protect the commercial interests of the discoverer or breeder of a crop variety in a similar way that patents, copyrights and other so-called intellectual property rights systems protect the interests of industrial inventors, authors and others, respectively. The intention behind these laws is to ensure a regular flow of new varieties to the farmers by stimulating research in the field of plant breeding through the granting of a certain level of ownership over the commercial exploitation of the variety.

Organisation
In Europe, this system has been widespread since the middle of this century, and the various national PVP-laws were reconciled in the 'International Convention for the Protection of New Varieties' of 1961. Signatories to the Convention became members of the International Union for the Protection of New Varieties of Plants (UPOV), based in Geneva. The Convention and UPOV were initiated by a number of West European countries but many more countries have joined since and adapted their national PVP laws accordingly. Member countries include most EU members, Norway, Switzerland, USA, Canada, Japan, Australia, New Zealand, South Africa, Israel, Hungary, Poland, Czech Republic, Slovakia, Ukraine, Argentina, Uruguay and Chile. This system gives the owner the monopoly in the commercialisation of the selection/cultivar. Because of the large scale of public plant breeding and the ample business opportunities for seedsmen with hybrid maize and its in-built protection, until recently, the USA had no legal variety protection: only a patent system for vegetatively-propagated crops (Townsend-Purnell Act of 1930).

Brazil, India, Indonesia, Kenya, and Zimbabwe have developed seed industries but have not applied for UPOV membership. Some have their own (active or dormant) PVP legislation. International pressure for developing countries to apply international patent conventions, including those on plant varieties, is increasing, however. This was a major issue in the 1994, General Agreement on Trade and Tariffs (GATT) accord. Signatories to this accord are obliged to adopt either a patent or some form of sui generis intellectual property rights system for plant varieties. Currently-operational sui generis systems are the 1978- and the 1991 UPOV Conventions, but alternative systems are being developed based on such codes as the UNESCO-WIPO Model Provision on Folklore or Investors' Certificates (Cricible Group, 1994). The UPOV secretariat is actively promoting its system worldwide but, from 1996 onwards, it will not be possible to join the more flexible 1978 convention. India has drafted a sui generis Act that includes a strong element of farmer protection and provision for compulsory multiplication in case of seed shortage.
(Turner, 1994): it does not meet, in full, the requirements of the GATT agreement.

**Scope**

PVP, as it operates under the UPOV system, grants ownership rights to the originator of a variety (plant breeders' rights). This may be an individual, a company or an institution. The owner has exclusive rights over the commercialisation of the variety and can produce and market the seed, or allow others to do so against payment of a royalty. The breeder/owner has to authorise any of the following steps in the seed production chain: multiplication, conditioning, offering for sale and actual selling, exporting, importing, or stocking for any of these purposes. The owner may claim rights over the harvested materials of his variety when these are obtained through the unauthorised use of propagating material (UPOV, 1991).

PVP, thus, has many similarities to other systems of protection for intellectual property, e.g. industrial patents, print copyrights, trademarks and industrial design protection. Substantial differences, however, originate from the essential biological nature of the protected material. Patents deal with non-obvious inventions: the right is granted after detailed description and examination, and is valid for a limited period of time. Copyright is obtained without prior examination and, as for trademarks and industrial design protection, operates without time limits.

**Procedures**

Application for the protection of a new variety is lodged with the Plant Breeders' Rights Office of each UPOV-member state. Technical information about the variety and the applicant, a seed sample, and administrative and testing fees are submitted with the application.

An official seed testing station sends the sample and the technical information to an institute for technical examination of distinctness, homogeneity (uniformity), stability, novelty, denomination, and some additional conditions regarding the eligibility of the applicant. Variety registration includes a check on the first three criteria: plant breeders' rights are granted on fulfilment of all six.

Normally, registration of a variety involves both growing the variety and examining the information supplied by the applicant. In the US system, a paper examination suffices. Variety registration authorities in UPOV-member countries co-ordinate these tests so that not every country has to perform tests for the hundreds of species that are eligible for plant variety protection. For example, maize registration research for most European UPOV countries is being carried out in France. The agronomic value of the variety is not taken into account for variety registration.

Once the variety has been accepted, its name is entered in the national Register of Varieties and an annual fee is payable to keep the variety on the list. This ensures that only the commercially-interesting ones are retained. A variety has to be registered in every country where it is to be marketed. The special co-operation between EU countries has resulted in an EU variety list that is valid in all member countries.

The listed criteria for plant variety protection research, need some clarification:

**Novelty.** This means that the variety has not been offered for sale in the country of origin, nor should it have been offered for sale in any other UPOV-member country in the four years preceding application for protection. This, therefore, excludes application for existing varieties or landraces that are commonly known in certain communities, and germplasm in genebanks.

**Distinctness** means that a new variety has to be clearly distinguishable from any other variety whose existence is a matter of common knowledge at the time of filing the application. There is an ongoing debate about variety-distances. Are varieties, that differ only in a simple band in an electrophoresis test, actually distinct? If so, plant breeders could be tempted to concentrate on finding small mutations in existing popular varieties rather than working on novel inventions. Different countries, even among UPOV members, have different views on this issue. Germany generally accepts such small differences, whereas in France, significant differences are required for registration in order to avoid this 'piracy'.

**Uniformity** means that, with the exception of the variation that may be expected from the particular features of the propagation material, the new variety has to be uniform in its relevant characteristics. An open-pollinated variety of a cross-fertilizing crop is thus allowed to be more heterogeneous than a pure line variety of a self-fertilizing crop. In official texts, the word 'homogeneity' is used because uniformity could also be influenced by environmental effects.

**Stability** means that the variety's relevant characteristics should not change after repeated propagation. A homogeneous variety is generally considered stable. Special conditions apply, for example, to hybrid varieties as these are inherently unstable.

Testing for DUS has been introduced in many countries in order to investigate the eligibility of a new variety for seed certification. A field inspector needs to know the distinguishing features of a new variety and its original level of uniformity to be able to perform field inspections. In practice, the tests involve the preparation of detailed variety descriptions on the basis of minimum description requirements (published by UPOV), and subsequent checking of this information against that of
similar varieties. Details of the variety description are listed as the distinguishing characteristics of the new entry.

During the same test, the homogeneity (uniformity) of the sample is checked. Homogeneity is normally the basis for stability: a uniform crop should breed true to type, except when the uniformity is based on uniform heterozygotes, such as F1 hybrids.

It is clear that these DUS tests require optimum crop care to minimize environmental influences within the plots. The trials, therefore, are very different from VCU (value for cultivation and use) trials, where the level of crop care should be similar to farmers' practices. Normally, DUS trials do not require a multi-locational set-up.

**Plant variety protection and patents**

The procedures described above are very strict and are similar to industrial patent regulations. However, the following are some very important differences between PVP and patents:

i. PVP can be granted for a variety (i.e. a group of plants with its specific characteristics) but not to the method used to obtain the new variety or to parts of individual plants. Patent rights govern ownership of the methodology and/or the product. A patent on plants or plant parts would also mean the breeder had legal ownership of the farmer's crop, and even the product. An absurd situation could then arise in that plants can reproduce themselves, e.g. when some grain is spilled alongside a road. These spilled grains cannot be taken to court for illegal reproduction of protected materials!

ii. The PVP right is based on novelty and on the DUS standards, whereas patents are granted on the basis of novelty, non-obviousness of the invention and on its possible use for the community. Because of the nature of the object being protected, PVP uses softer definitions than do patent laws: uniformity standards depend on the mode of reproduction of the variety. Standards for open-pollinated populations of cross-fertilizing crops thus depend on the average variability of the existing protected varieties of that crop. Such 'soft' definitions cannot be applied in standard patent procedures. Non-obviousness is an issue in PVP since even selections from obvious naturally-occurring populations can be protected (e.g. grasses). In PVP applications, no check is made on the variety's possible use for the community. VCU tests are not part of the PVP procedure.

iii. In practice, PVP rights do not apply to seed for private or non-commercial use. Farmers are allowed to produce seed for their own use: an important concession in that many farmers (even in more advanced agricultural systems) do not buy Certified Seed every season. In many countries it would not be easy to check for on-farm seed production to calculate the royalties due. In the 1991 UPOV Convention, the breeders' rights extend to any seed (including own production by farmers). A country may, however, allow farm-produced seed for particular crops while 'taking into account the legitimate interests of the holder of the Right'. This, basically, is the end of the farmers' privilege. Countries are, however, allowed to 'deviate' from this article (and maintain the farmers' privilege). Non-commercial dissemination of seed to neighbours is presently exempted in US laws only.

iv. Seed for experiments and further breeding is not affected by PVP. A variety can be used for further development and research (and inclusion in a new variety). This is not the case in patent rights. The protection of a wilt-resistant tomato is granted for the variety as a whole and not for the will resistance. A breeder who uses will-resistant genes of one variety to develop a second such (but very different) variety is under no obligation to the owner of the first variety. These regulations are also being tightened with the recent introduction of the class 'essentially derived variety', which grants rights to the original owner when a new variety differs very little from its protected parent (e.g. as a result of a mutation or genetic engineering). Bilateral negotiations are supposed to result in a sharing of the royalties.

v. Combinations of PVP with other property rights systems such as trademarks, are prohibited. Production of protected varieties bearing also a registered trademark, used to be very profitable once the validity of the former had expired (e.g. roses) but such combinations are now illegal according to the latest convention. A combination of patented genes in a PVP-protected variety, however, is allowed.

vi. The owner of a PVP-right has to maintain the variety true to its original description. The protection right expires as soon as the variety changes in any of its relevant characteristics or when it has lost its accepted level of uniformity. It can be prematurely lost, therefore, due to gradual genetic change. A patent can be declared null and void only when new information invalidates the original grant of the right. A breeder may withdraw his ownership/protection right before the end of the legal protection period should the cost of protection (including variety maintenance) exceed the expected revenues. The maintenance of varieties requires an obligatory continuous investment by the breeder.

**Recent developments**

Pressure is being exerted to adapt and tighten the rules relating to international plant variety protection. One of the major reasons for this is the increased use of biotechnological methods in plant breeding. Biotechnology has its roots in the use and manipulation of micro-organisms in the food-processing and pharmaceutical industries. Industrial patents can be obtained for innovations in such work. Recent developments in the field of biotechnology are towards its application in higher plants. Discussions, on the ethics of patenting genes of
living organisms, started in the USA in 1980 when a patent was granted for an oil-degrading strain of a bacterium. The case was that of Diamond vs. Chakrabarty (Anon., 1981). Over and above the ethical implications, such cases present serious problems for the existing plant variety protection regulations. Pressures to adopt PVP laws, however, are increasing due to developments in biotechnology towards application in higher plants and due to the considerable economic power of the biotechnology industry.

Unlike the situation with PVP, patents can govern use of both methodology and materials. The resulting problem can be visualised in the situation of a plant variety that contains ten engineered genes, each of which was patented by a different biotechnology laboratory. The variety is free for further research and breeding under the plant variety protection laws but the genes are not because of patent protection. A new variety, resulting from a cross with the protected variety has to be checked for the presence of any of these ten genes. Permission then has to be obtained from the different holders of the relevant patents before release of the new variety can be considered, and royalties have to be negotiated.

GATT discussions have resulted in a very interesting North-South debate which can be summarised as follows: if the North wants to apply patent-like laws on varieties and patents on genes (which often are natural genes transferred from one species to another), then the countries of origin of the species (often in the South) can claim patent rights over all the other genes of the plant species because they belong to the national heritage of the countries concerned; they have been developed or selected by the local farmers during the whole history of cultivation. This has led to lengthy discussions in various national (Gill, 1990) and international organisations. FAO has taken a stand in favour of these farmers' rights but, how to define such rights, has not yet been finalised.

It is likely that the UPOV system will continue to be pressed to change towards industrial patent right protection for genes, plants and varieties, especially because of the worldwide involvement of chemical and pharmaceutical industries in the seed sector. Most major seed companies are either owned by, or have strong linkages with, these industries which, in turn, are used to patenting their work. Whether or not the introduction of plant variety protection in developing countries will have the desired effects on the volume of breeding activity and the quality of released varieties in those countries and, whether or not the described development towards patent rights will bias this further, is unclear. Such considerations have to be taken into account when countries plan to develop their own plant variety protection system and when they want to streamline their existing laws with those of UPOV-member countries.

References in Chapter 5


6 Current issues

Three widely-debated issues that relate to seed supply are genetic erosion, the imminent decline in genetic diversity, seed supply in emergency situations and plant breeding for low-input agriculture. The genetic diversity issue includes consideration of the control and property rights of genetic resources and the options for germplasm conservation (in situ versus ex situ). Seed aid and seed security programmes, as alternative approaches to dealing with emergency situations, are outlined briefly in this chapter. Also, various breeding strategies for low-input farming are presented, including breeding for rather uniform marginal areas, selection for wide adaptation and breeding for heterogeneous farming conditions. Rather than present an in-depth discussion of these elements, this chapter seeks to demonstrate their links with seed supply systems.

Genetic diversity

Declining diversity

Selection, both by farmers and breeders, depends on the availability of genetic variation (Chapter 3). On a global scale, mutation and natural introgression from wild species to cultivated plant populations have been the main sources of genetic variation within crops. Both the rate of mutation and the percentage of potentially useful mutants are low, however. Also, the chances for introgression have become smaller with the intensification of agriculture. The low rate of increase in variation may not have been a limiting factor during the early millennia of agriculture when farming techniques developed slowly. For the past century, however, natural mutation and natural interspecific introgression have not been sufficient to supply the genetic variation needed to allow farmers to develop varieties that are able to keep pace with the rapid development of agriculture.

Modern plant breeding produces variation and aims to create varieties which meet the changing needs. In the more advanced countries, these resultant uniform varieties have replaced the local landraces to a very large extent - a trend that continues to affect agriculture in tropical regions. When this occurs in centres of diversity of crop plants (Chapter 2), potentially useful genes may be lost.

This gradual loss of global genetic diversity is called genetic erosion. The same term is used also in a more limited geographic context, such as for the loss of genetic diversity in a region, within a country or in individual farmer's fields. Concern about this trend focuses on the disappearance of the irreplaceable basis of plant breeding: genetic diversity.

Paradoxically, the spread of improved varieties replaces and, consequently, eliminates the resource upon which the improvements were based.

The need for protecting genetic resources

The first indication of the danger of planting large areas to a single crop with a limited genetic base was evidenced in the 1840s: Ireland and other parts of Europe experienced a great famine due to an epidemic of potato blight (Phytophthora infestans). It caused many people to die of starvation and many others to emigrate to the Americas. The genetic background could not even be guessed at: Mendel's theories were (re)discovered only several decades later.

The potential danger of crops with a narrow genetic base was acknowledged in the late 1930s, however, when uniform hybrid maize varieties, based on a limited genetic background, were introduced in the USA on a very large scale. The full extent of the risk was realised in 1970, when 15% of the maize harvest was lost to an outbreak of Southern Corn Leaf Blight (Drechslera maydis). This was due to adaptation of the pathogen to a cytoplasmic factor which was incorporated in 90% of the US-grown maize varieties at the time. The particular cytoplasm ('Texas' or 'T' cytoplasm) had been used for its male sterility-inducing capacity which allowed the hybrid seed producers to abandon the expensive manual detasselling operation in seed production fields.

Traditional varieties and wild relatives of cultivated species have been, and still are, important sources of resistance and other genes for the improvement of modern varieties.

The potential for, and effect of, a loss of genetic variation in the centres of diversity was debated as early as 1936 by Harlan and Martini with reference to barley in Asia and Ethiopia, and by Sauer in 1941 (both quoted by Kloppenburg, 1988). The Rockefeller Foundation, in preparing for its Mexican Agricultural Program (which later resulted in the establishment of The International Centre for Maize and Wheat Improvement (CIMMYT)) was warned by Sauer as follows:

'A good aggressive bunch of American agronomists and plant breeders could ruin the native resources for good and all by pushing their American stocks. And Mexican agriculture cannot be pointed toward standardisation on a few commercial types without upsetting native culture and economy hopelessly.'
The vulnerability of uniform modern varieties, so well illustrated by the Southern Corn Leaf Blight epidemic in the US, made it very clear that global conservation of germplasm is a priority for human survival. Further export of the Western development model to the Third World was criticised. A worldwide campaign on this issue, combined with other aspects of internationalisation of the seed trade and the growing commercial ties with the (agro-)chemical industry, was started in Canada and resulted in the controversial book 'Seeds of the Earth' by Mooney (1979). Defenders of modern agriculture and the seed industry stressed, however, that the industry had been capable of tackling the 1970 leaf blight disaster in a single year because of the same commercial seed supply infrastructure that was being criticised. It is a fact, though, that such an instantaneous reaction would not have been possible without the readily-available stock of genetic variation originating from the geographical centres of diversity wherein the co-evolution of host and parasites created a wealth of resistance genes in local crops.

Starting in 1943, the Rockefeller Foundation sponsored maize research programmes in Mexico and various Central American countries. Not only did these programmes result in the widespread use of hybrids there, but also in the large-scale collection of maize germplasm. Initially, germplasm was taken to the USA where public funds were made available for its conservation as a valuable input for the US maize seed industry. The National Seed Storage Laboratory was established in Fort Collins, Colorado in 1960. It became the largest of many genebanks. In the tropics, the international agricultural research centres (IARCs), including CIMMYT in Mexico, now maintain many important collections of germplasm.

FAO's World Information and Early Warning System on Plant Genetic Resources, which monitors all major genebanks in the world, reported that in September 1993, 3 820 000 accessions were stored worldwide.

FAO has played a significant role in the discussion on conservation of plant genetic resources. In the early seventies, its activities in this field were taken over by the newly-established International Board of Plant Genetic Resources (IBPGR) which, for some time, continued to be housed in the FAO premises in Rome. The object of the institute was to:

'promote and co-ordinate an international network of genetic resources centres to further the collection, conservation, documentation, evaluation and use of plant germplasm' (IBPGR, 1985).

In 1993 IBPGR separated from FAO and became the International Plant Genetic Resources Institute (IPGRI) under the auspices of the CGIAR. It maintained the same objective. In the meantime, FAO shifted its focus to discussions on the ownership issue of genetic resources. It launched 'International Undertaking on Plant Genetic Resources' (FAO, 1983). Plant genetic resources are widely considered a 'common heritage of mankind' and free access to such material is promoted extensively. In most industrialised countries, however, the multiplication of modern varieties and hence trading of the seeds is severely restricted under plant variety protection legislation. The FAO's attitude towards this issue is that if Western plant breeders' rights or patents have to be protected, the gene-rich countries should be financially rewarded for developing the landraces which form the bases of these legally-protected varieties. Compliance with these 'farmers' rights' should balance the hitherto negative financial effects that plant breeders' rights have had in developing countries. This discussion continues, meeting with both political (North vs. South) and technical/logistical problems. The latter concern chiefly:

- Whom to reimburse (small farmers still using landraces, national governments in gene-rich countries, or organisations working to preserve genetic variation throughout the developing world)?
- How to reimburse (especially difficult if small farmers have to be reached)?
- How much to reimburse?
- Who should pay?

Nevertheless, the FAO established the International Fund for Plant Genetic Resources to finance projects on conservation and utilisation of genetic diversity with donations from countries 'in recognition of farmers' rights' (Berg et al., 1991).

The discussion about the ownership of germplasm and related issues has yielded some very dramatic designations: 'seed wars' (Kloppenburg, 1988), 'gene hunters' (Juma, 1990), and 'the gene struggle' (Berg et al., 1991) are just a few. Such passionate wording may not facilitate the discussion between activists and technologists. A serious attempt to bring together a wide range of interested parties was the Keystone International Dialogue on Plant Genetic Resources. High-ranking officials of governments and NGOs, public and private researchers, and presidents of seed and biotechnology companies met with the aim of reaching a consensus on genetic conservation. All participants took part as individuals rather than as representatives of countries or groups. The meeting's conclusions and recommendations are now infiltrating the formal policies of national governments and international organisations. The Keystone Dialogue directly influenced the Biodiversity Chapter of the 1992 United Nations Conference on Environment and Development.

Collection and storage of genetic diversity

The initial response to the potential dangers of large-scale use of uniform varieties with a narrow genetic base, was to collect a wide diversity of germplasm. These collections are stored in genebanks which often have large cool- or cold-storage facilities (approximate temperatures are 5°C for short-term storage and -20°C for long-term storage). Storage of plant tissues in liquid nitrogen (-196°C) is applied for ultra long-term storage of germplasm (cryo-
preservation). Maintenance of large numbers of accessions requires expert management systems, especially with regard to selection, documentation, administration and physical renewal of samples.

The first major question to be decided is: which samples should be stored? Initially, collections were stored indiscriminately leading to storage of excessively large numbers of improperly screened and documented accessions. Handling of such large numbers in the necessary seed renewal programmes is extremely difficult, especially for cross-fertilizing crops that have to be grown in isolation. Another complication regarding cross-fertilizing populations is the question of the minimum sample size required to include the whole range of characteristic genotypes in order to avoid the risk of genetic drift during storage and renewal. Loss of samples during seed renewal is common in areas where the climatic conditions and disease pressures are different from the situation at the collection site. In addition, mistakes in sample administration and occasional mixing of samples (e.g. in seed cleaning equipment) are inevitable, despite careful handling. A specific problem is the transcription of sample names from, for example, Russian, Hindi, Mandarin or Thai scripts into Roman alphabetical characters. Different genebanks may store the same variety under different names.

Accessibility of a genebank collection is necessary for purposes of further breeding and, in this respect, documentation is important because collections are used by plant breeders who request material with specific properties. Because the number of characteristics of a plant is virtually without limit, documentation is extremely difficult. Forty years ago maize-collection managers could not have guessed that lysine content would one day be an important selection criterion. Also, current geneticists may not be aware of the presence of resistance genes against as yet unknown races of diseases that are present in collections. At the very least, therefore, documentation includes the so-called passport data (such as geographical source of the material, including a detailed agro-ecological characterisation of the growing conditions of the collection site), and a number of morphological and physiological observations. IPGRI is very instrumental in standardising the documentation systems of different genebanks through its descriptor lists.

Genebank management is relatively easy for annual seed crops such as cereals and pulses. For perennial seed crops, renewal of deteriorating seed samples is much more difficult. Propagation material of crops such as cacao (Theobroma cacao) and rubber (Hevea brasiliensis) whose seeds are recalcitrant, and vegetatively-propagated crops such as taro (Xanthosoma spp.) and dasheen (Colocasia esculenta) that do not set seed, cannot be stored for any reasonable period. Live collections in the field are prone to environmental vagaries such as cyclones or diseases, and to man-made problems such as theft or lack of garden maintenance. Tissue culture collections can be a solution to this problem (Withers & Williams, 1986; Bessembinder et al., 1993) but the methodology has not yet been worked out for all crops and the cost may be rather high if the growth of the plantlets cannot be reduced sufficiently.

Financial restrictions have a major influence on the decisions made by genebank managers with regard to the size and accessibility of their collections.

Strategies include:

- Collection of genes, i.e. holding an accession as long as it carries an allele that is not known in any of the other accessions. This requires extensive knowledge about the genetics of the crop involved.
- Removal of duplicates both within a genebank and between genebanks. Populations from the same source are not necessarily identical and the small differences among variants may be extremely valuable.
- Careful selection of new entries, i.e. only from previously unsampled areas, or samples with very specific, documented, characteristics.
- Systematic studies on genetic variation, leading to identification of core collections that represent the most important levels and types of variation (Brown, 1989; van Hintum, 1992). Material of lesser importance receives less attention. Fig. 6.1 illustrates the principle of core collections.

Duplicate collections are always stored at a second site in order to avoid irreparable losses due to natural or man-made disasters. An activity worth mentioning here is the construction of a large storage facility at Spitsbergen, Norway, where world collections can be stored at constant (naturally) low temperatures under geologically and ethnologically 'safe' conditions.

Other options for germplasm preservation

Despite the many collections that have been undertaken and the massive number of accessions stored in the various genebanks, it is not clear how much of the world's genetic resources are actually stored. Modern varieties, landraces, wild relatives of crops, and weeds and wild plants with no immediate value for food or industrial production, have to be collected, documented and stored. Decisions regarding how these operations are best carried out for each of these groups, increase in difficulty relative to the order of the groups as given above. Another consideration is that evolutionary processes, which are the basis of natural adaptation of plants, are halted by cold storage in a genebank. Other strategies, therefore, are needed to complement genetic conservation in genebanks.

An increasing number of national parks for animal conservation are taking on the added responsibility of preserving wild plants. The Worldwide Fund for Nature is an example of an organisation active in preserving parts of the rain forest. In situ preservation of the wide array of landraces of crops is a much more difficult but, nonetheless, important task. The main priority is to assure that landraces remain a part of the cropping systems in a wide variety of agro-ecological conditions. How can this be done? In some cases this question could be: how can
modern farmers be convinced to use varietal mixtures, (possibly as a side-line activity)? Farmers who have switched to growing modern varieties will not be easily convinced to revert to growing the ‘old fashioned crops’ of less sophisticated neighbours. It will be very difficult too to counteract the many years of propaganda devoted to commending these new varieties. Local landraces, however, are often grown for local consumption because of their specific taste, colour and consistency.

The philosophy of in situ conservation of crop genetic resources in areas where landraces are still grown, is not widely accepted yet. Brush (1991) lists the arguments most commonly used against it:

- genetic resources are ‘too important for mankind, to be left with untrained local farmers’;
- in situ germplasm is not readily available to breeders; and
- the farmers made responsible for in situ germplasm preservation would be condemned to perpetual poverty inasmuch as they are isolated from modern agriculture.

These reasons can be refuted for many agro-ecological and socio-economic conditions. The major advantage of in situ preservation is that both natural and human selection will allow evolution to continue and thus valuable characteristics will continue to be supplied for future breeders. To date, methods of in situ genetic preservation have not been worked out very well. This is due, in part, to the variety of natural and social conditions in which local genetic variation has developed and to the attitudes mentioned above.

Specific subsidy schemes have been proposed for farmers who willingly maintain ‘old’ landraces in areas where appropriate uniform varieties constitute a serious alternative. As with most farming subsidy schemes in the European Union, such schemes are not likely to operate smoothly in most tropical countries.

Where farmers are still using landraces of certain crops, they may be doing so for specific reasons. It could be that modern varieties do not improve yields under their specific agro-ecological conditions, or that they lack certain quality aspects. It may be due to deeply-rooted social customs, lack of availability or lack of alternatives. Research on such in situ conservation methodology, therefore, should be done in many different sites and with the help of the communities that are using traditional farming methods (De Boef et al., 1993).

Integrated seed supply systems geared to increase yields of local landraces can be instrumental in reducing the pace of the genetic erosion in farmers’ fields (Louwaars, 1995). In situ genetic conservation is among the main objectives of the bean programme carried out in central
Seed supply in emergency situations

Local seed supply systems are vulnerable, especially with regard to civil disturbance and ecological disasters. When crops fail, farmers may have no choice but to consume their last stock of food, i.e., their home-stored supply of seed for the coming season. Farmers in risk-prone areas are known to stock more seed than is required for one season’s planting. This is expedient in situations such as that of early planted crops being hit by a sudden drought and necessitating replanting. Muhammed et al., (1985) report such a situation in the drought-prone Machakos District in Kenya. Any extra seed can also be used as a security stock in case of failure. When two or more successive harvests fail, farmers face severe problems. Social structures, which may solve individual shortages, may not be effective in cases where large areas are affected, by drought, in a uniform manner. This can also be true when large areas are affected by social disturbances. Difficulties of this nature were widespread in the western Sahel (during the 1970s and 1980s) due to drought, in Rwanda (1994) due to civil war and in the Horn of Africa due to a combination of drought and political unrest.

The international community’s usual immediate response to such disasters is to provide food aid. Relief operations of this sort may be necessary to address acute shortages of food in the short term but wrongly-targeted food aid can cripple local agricultural production by decreasing commodity prices. Restoration of the supply of agricultural inputs such as seeds and basic implements, like hoes and machetes, is a first step to rehabilitate local food production.

Basically, there are two methods to improve seed supply in emergency situations:

i. supplying seeds to the farmers in the affected areas (Seed Aid Programmes); and

ii. improving the seed production and storage capacity in the area itself (Seed Security Programmes).

Seed aid programmes

In a very severe situation, such as a massive resettlement of refugees, there is no choice but to supply the basic needs for farming of which seed is one of the most vital. The source of this distributed seed can have a significant impact on the success of such an aid programme.

Donor agencies generally try to purchase Certified Seed of adapted varieties for distribution, because its viability and purity are guaranteed. Also, such purchases are relatively easily transacted by the executing agency which merely has to pay a single supplier, after which the logistics of delivering the supplies to the affected areas and distributing them to the farmers has to be organised. These organisations are experts in logistics—not in agriculture or seed technology.

Seed aid programmes of this sort can work very well if the varieties are truly adapted to the target area’s agro-ecological and socio-economic conditions. However, since disasters can affect large areas, and the certified seed often has to come from afar, there is a significant risk of insufficient varietal adaptation which may lead to crop failure or reduced acceptance of the product. To avoid these problems, the aid programme can be adapted such that varietal adaptability is ensured and rehabilitation of agriculture in the affected area is enhanced: local (small) stocks of food grain are identified, bought and distributed as seed (possibly after cleaning, testing and treating if necessary). The major problem with this method is that it requires a lot of work for the executing agency: staff have to be sent to the area to identify stocks, make the deals, collect the local seed and condition it for distribution (cleaning, packaging). Another concern is that the large number of cash transactions involved can create problems of accountability and facilitate corruption. This is a situation that donors and executing agencies want to avoid at almost any cost. Financial control can be strengthened by bartering food grain for the last reserves of local grain at a fixed rate. Provided the germination capacity of this grain is acceptable, it can be distributed throughout the region as seed.

When treated seed is distributed free of charge, there is the added risk that it will be consumed by hungry recipients. Cases of poisoning due to consumption of Lindane-treated groundnut and sorghum seed have been reported in East Africa in recent years.

Seed security programmes

Seed security programmes have been initiated in risk-prone areas, such as the Sahel, as part of emergency programmes. Local seedbanks have been set up in Mali and Sudan, for example, by various NGO’s. This involved the construction of suitable centralised storage facilities to be run by village committees. Farmers ‘borrow’ seed at planting time and repay in kind after harvest. Cromwell and Wiggins (1993) described difficulties in maintaining such schemes due to insufficient administration and unequal
distribution according to power and political favour. Another major problem occurred in very dry seasons when farmers were unable to repay their seed loans and the system was doomed. Renewed financial input from the donor organisation was required for its re-establishment. Some seed stores reverted to selling seed for cash, thus operating rural credit programmes rather than seed security programmes.

Campa et al. (1993) reported on such rural credit programmes, in the Andean region, that involve mainly seed production and distribution. The availability of high-quality potato seed and the investment required were identified as two major problems in the production of this important food crop. A 'Seed Revolving Fund' was developed to improve the situation. The Fund provides loans in kind to communities: not only seed, but also other agricultural inputs and technical assistance. The communities repay the loans with seed potatoes and use the balance. Thus the availability of high-quality seed is increased. The seed returned to the project can be used to involve more communities in the scheme.

Plant breeding for low-input agriculture

Ever since the Green Revolution took place in the 1970s, there has been an ongoing discussion about its benefits not reaching the small farmers to any significant extent. As yet there is no consensus regarding objectives and methodologies for developing special breeding programmes for small farmers but, commonly, the following views are advanced:

- varieties that outyield local landraces under good conditions (favourable environment, high input) will also do this under less favourable conditions, so there is no need for special breeding programmes;
- selection and breeding for low-input farming is not feasible because of expected low heritabilities of the important quantitative characters under such conditions; and
- low-input farmers grow crops in highly variable environments, so it is not possible to define common breeding objectives.

So far, little progress has been made in this debate mainly because the variety of environments in which low-input agriculture takes place has not been acknowledged sufficiently.

Without pretence of detailed coverage of the scientific background of the proposed strategies, this section highlights the main issues in this debate. An attempt is made to refute the universal validity of the three statements presented above.

In order to resolve the problem of definition referred to above, the following classification of low-input farming environments is proposed:

- low external-input agriculture (LEIA) in large, ecologically rather marginal but relatively uniform areas;
- low external input agriculture in areas with large agro-ecological variation (e.g. mountainous regions); and
- farmers cultivating under heterogeneous cropping conditions.

The feasibility of breeding for these categories of small farmers, and options for adapted breeding strategies, are discussed below.

Breeding for LEIA in large, relatively-uniform, marginal areas

In the case of large areas where specific stresses limit crop production levels, the target environment can be characterised rather well. Examples are the acid soils in large areas of southern Brazil or the drought-prone areas of North Africa, Southwest Asia, Western Australia and the midwest of the USA. Breeding strategies can be directed to selection for tolerance to such stresses. On-station screening of germplasm for tolerance to some of these stresses can be effective. Tolerance to others can be physiologically complex and controlled by large numbers of genes, making laboratory screening difficult.

In general, field trials at research stations are well managed, including timely land preparation, planting, weeding and fertiliser application. Additional irrigation may even be applied when a trial is in danger of failure because of excessive drought. Often, these measures are taken primarily to reduce the environmental variation within a trial, thereby increasing heritabilities and selection potential. The result is that certain stresses, that can be real constraints in farmers' fields, are not taken into consideration.

Such trial management is a result of the (un)conscious assumption that lines that perform well in high production environments will also outperform others under poor conditions. In many cases this is true but, often, there are interactions between genotype and environment (GxE) that distort the selection process. Fig. 6.2 shows such GxE interactions. The production level of the testing environments (e.g. the trial means) is plotted against the x-axis; the y-axis represents the yield of each variety in the trial. Such graphic representations have been used extensively to analyse varietal performance and, especially, yield stability, over a range of environments.

Eberhart & Russell (1966) defined varieties with a slope close to 1 (i.e. consistent production in each environment in relation to the other varieties in the trials) as being most stable. In addition, they identified a second measure for stability: the standard deviation of regression. Joppa et al. (1971), on the other hand, considered this a stochastic (error) factor. Finlay & Wilkinson (1967) regarded a limited slope to correspond with highly stable
Figure 6.2  Varietal responses to different environments: interaction types and yield stability

Figure 6.3  Varietal responses to different environments: wide adaptation.
genotypes (actual production levels remain constant over the environments).

Blum (1988) summarised the viewpoints of Eberhart & Russell, and Finlay & Wilkinson as being 'horizontal' and 'vertical stability', respectively.

Variety A, in Fig. 6.2, yields relatively well in poor environments but responds little to improved growing conditions. This is typical of many local varieties (landraces). Breeders will try to find a variety B which yields higher than the original one throughout the environments, or a variety C which is higher yielding and highly responsive to improved growing conditions (e.g. inputs like fertiliser and irrigation). Variety C will give a higher return on investment. In cases B and C, there is a GxE interaction with variety A but, in these cases, selection is not affected and the statement that varieties that perform well under good conditions will also perform better than the standard under poorer conditions, is valid.

In many cases, however, variety D is selected. When compared with A it is highly responsive to inputs but, under poor conditions, yields are low compared with the original variety. This is called cross-over interaction. Varieties that are highly responsive to improved cultivation conditions will also respond to suddenly worsening situations, i.e. their vertical yield stability is low.

It should be noted that an apparently straightforward trial result (comparison of varieties A and C) may change dramatically when yet poorer yielding environments are taken into account; these varieties then may also show a cross-over type of interaction. In practice, interactions always result in a cross-over situation, but they only affect the selection decision when the lines cross within the range of environments studied.

Ceccarelli et al. (1992), in studying barley in ecologically-stressed environments, showed that heritabilities are not necessarily low when testing is done in low productivity environments and that selection for low input agriculture can be very effective as long as the testing environment is chosen correctly, i.e. at stress and production levels that are similar to those under farmers' conditions in the target area. They emphasise, though, that sufficient attention has to be paid to trial management procedures.

Another approach is to select for wide adaptation. This means that selection is aimed at increased yields over a wide range of environments (varietal plasticity). The simple calculation of the average yield over a large number of trial sites may result in the selection of variety E among the varieties A, D and E in Fig. 6.3. This variety is neither the best in poor (the best is A) nor in good environments (D is best). In a wide range of intermediate environments, variety F is to be preferred. Wide adaptation is defined here in relation to the existing varieties. It is neither directly linked with the slope nor the standard deviation of regression. Wide adaptation is, therefore, not linked to yield stability.

When large areas are involved with relatively uniform stresses, breeding methods may not have to be changed dramatically as long as the testing environments correspond with the conditions under which the target farmers produce.

**Breeding for heterogeneous areas**

Breeding strategies may differ from the above in areas where agro-ecological differences between plots may be significant at short distances while the within-plot heterogeneity may be small. These could be mountainous areas, where ecological conditions change over short distances. Temperature regimes, for example, vary with the altitude and position of the slope; water supply and soil characteristics are variable within topo-sequences. Even in ecologically-uniform areas, differences may occur when socio-cultural differences evoke specific requirements for a crop, e.g. farming methods and consumption values (Dc

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*Plate 6.1 Very marginal conditions for barley cultivation in Northwest Syria*
Breeding for heterogeneous farming conditions

Low external input farming is often characterised by a high level of heterogeneity within farms and even within plots. Manual land preparation, lack of added fertiliser and a range of crop associations allow for a significant within-plot heterogeneity for moisture availability, soil fertility, etc. Often, variable conditions are associated with the cultivation of landraces.

Modern breeding methods geared to the development of uniform varieties for specific environments are not suited to address such agrodiversity (Struik et al., 1995). The environment cannot be characterised and thus selection cannot be directed. The only option to increase the genetic yield potential in such situations seems to be to offer farmers a wide range of genetic materials and to allow them to select for their specific conditions (Chapter 4).

Farmers’ knowledge of varieties and varietal adaptation to specific farming conditions is being recognised, increasingly. Modern breeders cannot be expected to understand every individual farmer’s intentions or share his or her knowledge of specific agro-ecological and socio-economic situations. Breeders, however, have a moral duty to integrate their germplasm and knowledge with these local seed systems.

References in Chapter 6


7 Case studies of seed supply systems

Four case studies that complement the previous chapters are presented here. They were chosen because, by bringing together aspects of different chapters, the complexity of seed supply in developing countries is well illustrated. Examples are selected from three continents and each is an example of widely differing (groups of) crops.

The first case deals with potato seed supply in Peru and describes the (mainly local) seed supply system, efforts towards integrated seed supply and the influence of commercial potato cultivation on the seed supply system. Sanitary quality aspects play an important role. A second case, namely that of the On-Farm Seed Project in Senegal and The Gambia, is described in order to illustrate how integrated seed supply can be aimed at by employing a participatory approach. The third case presents the organisational patterns of the formal maize seed industries in four countries in East Africa. Differences are discussed and related to historical events and government policies. In the fourth case, the emergence of a commercial vegetable seed industry in Southeast Asia is presented. The strategies and decisions made by the East-West Seed Co. Inc. are followed throughout the company's existence. The impact of government policies regarding business promotion in general, and of seed industry development in particular (e.g. variety release), are illustrated. Included in the discussion are the importance of different quality aspects, the use of local material and the impact on local seed systems.

7.1 Seed potato supply in Peru

History and ethnobotany

The potato (Solanum tuberosum L.) has been one of the major food crops in the central part of the Andes ever since the early civilisations. Its domestication, and that of other tuber-bearing Solanum species such as S. genistoides, S. stenotomum, S. × chauca and S. × juxepalae and subspecies like S. tuberosum ssp. andigena, reportedly started around Lake Titicaca (Horton, 1987) on the Bolivian/Peruvian border and may well have been one of the most important prerequisites for the establishment of the Inca empire. Another important species, S. phureja, originates from the lower humid areas (see Fig. 7.1) but this species is also grown widely in the higher altitude areas.

A wide genetic range of the crop is planted in the various ecological zones within the central Andean region and extensive local knowledge of the crop has been built up over time. Various anthropologists and sociologists have reported on the farmers' detailed knowledge of the different types of potato and of the adaptation of these different types to altitude, soil fertility and water balance. This local knowledge also extends to cover a wide variety of the culinary values of the different types of potato.

Brush (1980) describes a well-developed local taxonomy wherein a distinction is made between four major groups. Within the two cultivated groups, 'races' are distinguished and, within some of the races, sub-races are identified. The identifications are done on morphological characteristics of the tuber and serve as markers for large numbers of agronomic and culinary values that are known for each type (Clawson, 1985). Morphological characters such as plant habit, flower colour and stem colour, though widely used in modern cultivar identification, are rarely used in these local taxonomies.

A different classification is presented by Zimmerer (1991), who found that farmers categorise their potatoes according to the purpose for which they are grown e.g. boiling, soup making or earning cash. Within each category, different cultivars and sub-cultivars are identified using binomials for the lowest sub-division, similar to Linnaean taxonomic nomenclature. Different genotypes are planted in a mixture such that each type is planted, in those fields and areas within fields, where the soil conditions suit the genotype. Van der Ploeg (1990) calls this extensive local knowledge the 'art de localite'.

Together with these intentionally-composed mixed fields based on agronomic and culinary knowledge, many farmers actively operate experimentation plots in which new introductions, mutations and possibly even seedlings of intra- and interspecific crosses are tested extensively. These so-called 'chacritas' show an amazing level of genetic diversity which is deliberately maintained as a cultural heritage and to maintain future options (Brush et al., 1980).

The agronomic importance of these mixtures is based on the yield stability derived from the various reactions of the different genotypes to biotic and abiotic stresses. Furthermore, the differences in storage potential and consumption qualities have to be represented according to the farmer's needs. Finally, the marketability of the different types plays a role in varietal choice. Zimmerer (1991) proposed yet another reason for the planting of a variety of genotypes. His observation that most farmers plant a very constant number of varieties in each plot, led to the conclusion that potato diversity is culturally determined. The farmers in the valley where Zimmerer did his research appeared to have a culturally-determined perception of how
(variable) a potato crop should appear. Irrespective of the
genic composition of the crops, the level of diversity was
very similar for all the farmers.

Agro-ecology and seed supply
Traditionally, most potatoes in Peru are grown between
3000-4100 m above sea level. This includes almost the
whole arable area of the Peruvian Sierra. Figure 7.1 depicts
a cross-section through the Andes, showing important
potato growing areas. With the urbanisation of Lima,
potatoes are now also grown widely in the lower valleys of
the Sierra and in the low coastal areas. The conditions in
the lowlands are not optimal for the crop but the presence of
a market in the vicinity makes cultivation profitable.

The main problems associated with growing potato
crops in hot climates are linked with diseases and pests.
Fungal diseases can be rampant under the relatively warm
and humid conditions in the coastal plains but high levels
of fungicide treatments can keep production losses at
acceptable levels. The spread of virus diseases corresponds
with vector activity, especially that of aphids (which are
absent in cooler areas). Soil-borne bacteria thrive in warmer
soils (below 2000 m). Recently, the tuber moth (which
cannot be controlled by chemical means) has become by far
the most serious problem in the formerly highly-productive
Cañete Valley, south of Lima. Nearly all these diseases and
pests are seed- (tuber) transmitted.

Urban markets require a uniform product. In contrast
to the vast deliberate genetic (and morphological) diversity
in the more distant valleys and slopes, uniform varieties are
grown in areas where commercial potato production for the
urban markets prevails. The Mantaro Valley, with the town
Huancayo as the commercial centre, is one of the major
potato 'exporting' regions of Peru due to its good
infrastructure connecting the area with Lima. The flat areas
in the valley are owned by economically-stronger farmers
who use relatively high levels of inputs and have
significantly higher physical and economic yields. The
higher slopes are used mainly for subsistence agriculture.
These valley farmers get the best economic returns from
investments in uniform varieties (Table 7.1).

![Diagram](image)

**Figure 7.1** Cross section through the central Andes in Peru showing the Mantaro Valley in
the Sierra and the Cañete Valley near the coast

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield per producer group (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>small</td>
</tr>
<tr>
<td>modern</td>
<td>3.1</td>
</tr>
<tr>
<td>traditional</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Source: Franco *et al.*, 1983
For the sake of this review of seed supply systems, three groups of Peruvian potato farmers are defined:

- small-scale farmers in highland areas remote from the major markets who plant mixtures of potatoes primarily for subsistence;
- larger-scale farmers who farm the floors of the most accessible valleys and produce high quality potatoes for the market; and
- farmers in the coastal plains and the Cañete Valley close to Lima, who produce ware potatoes primarily for the urban market.

The supply of seed potatoes for these three groups of farmers is reviewed below.

Seed supply for small and remote farms

In the main, the small farmers who plant varietal mixtures on the Puna (3950–4200 m) maintain their own seed stock. Usually, potatoes are graded and selected before the planting season. Zimmerer (1991) described how, for each plot, the user groups of varieties are selected on the basis of different clones with similar culinary characteristics. Within the user groups, specific levels of diversity are selected. van der Ploeg (1990), on the other hand, claimed that minute differences in soils are taken into account when individual clones are selected for planting.

Crisman & Lequillas (1989) found, however, that the above-mentioned 'ideal' situations of combined local knowledge and crop genetic composition do not apply regularly with the smallest farmers because, often, they are unable to keep sufficient seed. They depend on local sources such as neighbours, relatives, or local markets. Especially at the slightly lower elevations, diseases may build up in the seed stock. Healthy seed from higher areas is regularly purchased or bartered, therefore, to replace the degenerated stock. Rhodes et al. (1988) found that a replacement rate of 5–6 years is common. Traditionally, farmers plant a number of plots in different ecological zones (altitudes) in order to reduce risks (Mayer, 1979). Thus, a seed flow from higher to lower altitudes can also occur within households.

Certain areas, such as the eastern slopes of the Mantaro Valley, are renowned for their high-quality seed potatoes. Farmers who produce more than is needed for home consumption may plant their 'old' potato varieties for home consumption and payment of labourers and, in separate plots, may plant modern uniform varieties to sell. Many modern varieties are not popular because of their poor consumption- and storage qualities. Their higher yields, however, may offset these negative values, especially for market production. In general, prohibitive prices mean that most of the seed reaches only the larger farmers in the Sierra and commercial farmers near Lima. A few small farmers may get these new varieties through a national certified seed programme but most modern varieties spread through the informal systems (Esca & Scheidegger, 1985). Franco et al. (1983) illustrate the effectiveness of these informal channels. When the International Potato Centre (CIP) started to disseminate the varieties Molina and Cajamarca through the national potato programme, they found that many farmers in the Cajamarca Valley had already been growing them for five years. Further knowledge of how the informal seed systems operate is regarded as being important also for in-situ conservation of plant genetic resources (Brush, 1991).

Seed supply for large and accessible farms

For some time, large farmers who cultivate the floor of the Mantaro Valley have supplied the emerging Lima market with ware potatoes. They produce potatoes of such high quality that traders started to purchase them for planting under irrigation in the dry Cañete Valley close to Lima. The cost of transporting table potatoes to Lima has been cut considerably in this way and the profitability of potato cultivation in the Mantaro Valley strengthened because the product could be sold as seed. Good quality seed sometimes generates four times the price of ware potatoes. The use of fungicides, however, increased in the Mantaro Valley because of increased quality requirements. This allowed only the financially-stronger farmers to reap the benefits of such development. These farmers concentrate on seed production without formal seed-quality control and certification. Many traders who supply seed potatoes to the Cañete farmers protect their businesses by maintaining high quality standards. Others, on the other hand, prefer the short term profit from supplying poor quality seed to the coastal valley farmers who, therefore, cannot always rely on the quality of the seed from the Sierra. The result of this specialisation in seed potato production is that varieties not optimally adapted to the Sierra are planted extensively in the Mantaro Valley for 'export' to the coastal region.

In 1955, the Ministry of Agriculture launched an extensive programme whereby Basic Seed from the research stations entered special multiplication projects in the Mantaro Valley. Semi-commercial sales and special extension programmes were established to disseminate the new varieties and what was anticipated to be top quality seed (Monares et al., 1988). These certified seed programmes appeared to be less efficient than the unofficial seed production programmes launched by the potato traders: the seed quality was not interesting enough or the price was too high for the targeted customers (Horton, 1984). Recently, the official programme was reduced to the maintenance of small quantities of guaranteed virus-free seed and its dissemination in the area for field testing and incorporation in the local and commercial informal seed systems (Fig. 7.2). Because of the realisation that the failure of earlier seed programmes was due largely to a top-down project philosophy, this production and dissemination of virus-free seed was done with continuous farmer involvement (Prain et al., 1992). Prain and associates summarised the seed potato market in Fig. 7.2. A small
The new technology of true potato seed (TPS) may significantly improve the seed quality for growers in disease-infected areas. Whereas most of the important potato diseases are transmitted by the vegetative seed, very few are carried by botanical seed resulting from fertilization of an ovule. Seeds of the latter type produce small tuberlets in the first season of cultivation but when produced under well managed conditions, high quality seed potatoes for commercial planting can be obtained. It requires the care of a horticulturist to raise such seedlings.

This technology, initially, was meant to serve the small farmers who cannot afford to buy seed tubers and who, it was supposed, would not be very concerned by the expected genetic variation caused by cross-fertilization of the highly heterozygous tetraploid potato. Hybrids that produce a relatively uniform crop are now available and, in recent years, the technology has been perfected by CIP scientists. Adoption of the technology by commercial farmers in the southern coastal valleys has proven that they too can benefit from the new technology.

References in Section 7.1


7.2 Participatory seed development in Senegal

A good example of integrated seed supply is that of the On-Farm Seed Project (OFSP) implemented in two regions in Senegal (Casamance and Sine-Saloum) and in The Gambia. It started in 1987 and demonstrates well how integrated seed supply can be aimed at in a participatory approach.

With the US-based NGO, Winrock International coordinating the project, the overall goal was to identify and promote improved methods of selection, production, storage and distribution of seeds and vegetative planting materials as developed by small-scale food crop farmers. The importance of seed in the farming system was described as follows: 'No matter how fertile the soil, plentiful the rain, or knowledgeable the farmers, a good crop is not possible with bad seed' (Seed Sowers/Les Semeneurs Vol. 1, No. 1). It was envisaged that improved seed would increase local productivity. In addition, it would be a source of additional income for those most successful in producing high quality seed.

Approach

The project's approach is people-oriented and, compared with seed projects in the formal system, is less concerned with institution building. Among other objectives, it aims to help farmers and NGO staff identify potential strategies for exploiting indigenous knowledge and skills. This requires a thorough understanding of the traditional system. In addition, new technologies may be introduced where the local methods fall short. It uses a multiple-source model for technology innovation wherein national and international research centres are just two examples of sources of new technology. Farmers themselves are another very important source of innovation: they are not just 'consumers' of new technology.

The OFSP aims to have an impact on the target group farmers but, also, to promote the flow of information from the farming community to the research system. By articulating questions on practical matters, the project also urges the research system to work on technologies that can be adopted directly by farmers. Incidentally, the formal research system could be assisted by the international network of the project.

An important aspect of the programme is sensitivity to gender issues. This is illustrated by the choice of food crops on which the project focuses and, in some cases, by the choice of cooperating organisations, some of which work exclusively with women (e.g. a Women's Rice Project). Food crop production in Senegal is often a women's task, whereas men take responsibility for cash crops. Improving food crop production through low investment technology (credit is rarely available to women) directly improves the position of women. Food crop seed production and sales within the community can even provide some cash income for these women.

Methodology

The OFSP started by identifying, within the area, ongoing small-scale projects with a seed-related component. Often, such projects are executed by NGOs. The role of Winrock as intermediary was to liaise between local initiatives
(including NGO projects), national research and seed production institutions, and foreign experts. US universities and private voluntary organisations (PVOs) are of particular importance as sources of foreign expertise. For example, Mississippi State University is used as a major source of seed technology knowledge and experience; and the PVO TechnoServe provided assistance in marketing and development of (small scale) private enterprises.

Strong emphasis was laid on training NGO-workers and others who have direct contact with farmers. They were made aware of the potential role of better seed in agricultural production and, subsequently, in improving the nutritional status of the local communities. Training was given in the basic principles of seed selection, production, and conditioning. Thus, through the project, a wide range of organisations that work with farmers were brought together with institutions having relevant experience and research capabilities. Major issues were identified, including problems associated with local storage of groundnut seed (particularly insect damage) and yield increases through the introduction of new varieties of various crops into the local seed system. As an example, the experiences with rice variety testing are discussed below.

Although the OFSP was started to deal with seed issues, aspects of soil fertility were identified as being a second major group of limiting factors in food production. Therefore, the project expanded its focus to include some aspects in this field. The experiences gained in this On-Farm Seed Project resulted in the On-Farm Productivity Enhancement Program (OFFEP) which is in operation both in West and East Africa (Antoine & Bymes, 1993). Seed and soil improvement are equal objectives of the OFFEP.

Participatory rice research in OFSP-Senegal

An important feature of the project was its use of existing technology to solve actual farming problems. When, for example, a production-limiting factor could be eliminated by using other crop varieties, the first task of the project was to liaise with the research system and check whether potentially suitable material with the desired characteristics was present in the germplasm bank or the breeding programmes. The characteristic top-down approach of the Institut Sénégalais de Recherche Agronomique (ISRA) with its poor research-extension linkage was considered to be a reason why potentially valuable varieties might not have reached the farmers. Osborn and Faye (1991) documented the history of the development of ISRA and its extension infrastructure. Most of this case is drawn from their paper.

Constraints to sustained rice yield increases were identified as follows: non-availability of appropriate rice varieties, poor water control, shortages of fertiliser and other inputs, poor weed control, shortage of labour, inadequate rainfall and failure to consider traditional production practices and ethnic factors. In seeking to address these limiting factors, OFSP played an important role in

interesting ISRA researchers in finding alternative methods for interacting with farmers. A rice agronomist, in cooperation with Peace Corps volunteers in the villages, collaborated closely with the project to develop a process to gain knowledge and understanding of the seed-related problems of farmers.

In the Casamance region, cultivation of both *Oryza glaberrima* and *O. sativa* was found to be highly affected by the drop in water level of the Casamance river and, in particular, by moisture deficiencies during the crop’s flowering phase. Decreased river levels increase the risk of salt-intrusion, from coastal mangroves, into the paddy fields. Group interviews (mainly with women but including village leaders) were followed by field visits with individual farmers. Two distinct approaches to rice cultivation were identified: each was named after one of the two main ethnic groups, the Diola and the Mandink. The use of each system, though, is not restricted to any one ethnic group. The farmer system is characterised by: the use of small plots (ca. 200 m²) of transplanted rice in riverine ecologies where some water control is possible; male involvement in land preparation (often with animal traction); and fertility management through grazing of the stubble and the application of manure and ashes. Weeding is seldom necessary. Each farmer uses 2-5 (in most cases, traditional) homogeneous varieties that flower and fill grain in the drought-prone month of October.

In the Mandink system, women are solely responsible for cultivation in inland swamp valleys where water control is minimal but salinity is not a problem. Land preparation of their larger plots (2000 m²) is done by hand. Most rice is broadcasted and weeding is important. Yields in both systems average 800-1000 kg/ha.

Physiological seed quality was not a major problem. Farmers keep seed separate from food grain in the attie of their houses. Germination is high, but insects and rodents become problematic during seed storage.

Because of the different rice production systems in the area, different strategies are needed for dealing with seed-related problems, both for the method of dealing with farmers (gender aspects) and in addressing possible technical constraints. For example, the introduction of mechanical land preparation (tractors) could benefit the larger-scale Mandink system but not the Diola system. In the latter system, the local tools are valuable in dealing with salinity and iron toxicity.

In order to reduce the risk of yield reduction due to drought in the grain-filling stage of the rice crop, early-maturing varieties were identified at ISRA. These varieties were planted by farmers or farmer groups in their own fields. Credit and inputs were not supplied by the project in order to avoid over-estimation of the introduced technology due to management aspects. Other characteristics of these varieties were: higher harvest index; higher tillering capacity; compatibility of grain size and other quality aspects with local preferences; and blast resistance.
Two different sets of cultivation practices were tested: in the Diiola system, seed treatment for the nursery beds and early transplanting to increase tillering; and row planting, allowing early more efficient weed control, in the Mandink system.

Much emphasis was placed on discussing the trials with the whole village community. Despite some risk that demonstration plots received more attention (better management) than average, many farmers were easily convinced of the trials' merits because yields in the demonstration plots were more than 40% higher.

All parties were involved in evaluating the trials. Some major issues were:

- Are the technologies good for the farmers? Do women benefit from them?
- Do the seed-related issues make a valuable contribution to the objectives of the participating NGO's and the individual volunteers in the field?
- Is farmer-participatory research valuable for the operation of ISRA? Is this type of work compatible with the many other duties of the individual researchers?

External advisers (e.g. Mississippi State University) should be asked whether they too derive any satisfaction from cooperating in this way and whether or not they gained information that can be used in research and teaching.

Conclusion

Subjects cannot be identified beforehand in participatory research. This is illustrated by the fact that, in one system, seed treatment was identified as a priority second only to the introduction of new varieties; in the other, row planting was suggested to ease weeding. It is difficult, therefore, to carry out a participatory research and development project on seed issues alone. However, it is of the utmost importance that integrated seed supply is aimed at in farmer-participatory research and that farming-system researchers, extension workers and NGO-staff have a good understanding of the potential role of small improvements in seed selection, production and storage. Unfortunately, formal knowledge of seeds is usually restricted to seed production and certification staff. Projects like OPSP play an immensely important role in bringing seed issues to the attention of general agronomists and, of course, farmers.

References in Section 7.2


7.3 Maize seed industry development in East Africa

In East Africa, maize is the next most important food crop, after millets and cassava (and plantain in Uganda). Maize seed production is the major enterprise of formal seed supply organisations throughout the region. The form, size and effectiveness of the organisation of maize seed production in these countries, are very different. This case study presents the history of the development of national seed production organisations in Kenya, Uganda, Malawi and Zambia. Differences between the organisational patterns of the formal seed industry in each country, are described. Analysis of these differences can give a good insight into the effects of historical developments, including government policies and private enterprise decisions on formal seed industry development (Chapter 3).

The seed industry in Kenya

The development of the Kenya Seed Company Ltd. (KSC)

In 1956, settler farmers established the KSC in order to develop and produce improved grass seed. Maize research started in Kitale in the same period but, only in 1963 when the first commercial hybrids were released, was maize seed included as the second important KSC commodity. These hybrids were developed initially for the commercial farmers (half of whom were already using hybrids by 1966). They were also adopted rapidly by many small-scale maize farmers (Fig. 7.3) especially in the high-potential Rift Valley and neighbouring Central and Nyanza provinces. This adoption was boosted by the subsidised distribution of fertilisers and the rapidly expanding market as a result of population growth and urbanisation. Ten hybrids and four composite varieties were grown for seed in 1993 (Table 7.2).
Figure 7.3 Development of hybrid maize seed use by large-scale and small-scale farmers (Ochieng, 1985)

KSC designed an effective marketing structure: the Kenya Farmers Association (KFA), acting as the Company's agent, distributed the seed to sub-agents and many different retail outlets throughout the country. This distribution was supported by information/promotion campaigns (see maize diamonds, Chapter 3) which were effective in reaching many small farmers and in encouraging adoption of the technology. Hybrid maize seed sales climbed from less than 2000 t in 1967 to over 15,000 t in 1984 (Ruigu, 1988).

The Company lost a significant amount of support with the departure of settler farmers around the time that Kenya gained its independence. A large proportion of the shares were taken over by the government and placed under the management of the Agricultural Development Corporation (ADC).

The ownership structure thus became: ADC 52%; Kenya Grain Growers Cooperative Union (KGGCU, formerly Kenya Farmers Association) 28%; and private investors 20% (Ruigu, 1988). The Company continued to operate successfully under sound commercial management and strict internal quality control. It expanded its range of seed crops to all major food crops (wheat, barley, sorghum and sunflower), and fodder and vegetable crops (by its subsidiaries, Simtum Seeds and HortiSeed Co.). For all these crops, the Company operates its own breeding/screening programmes in cooperation with the centres of the Kenya Agricultural Research Institute (KARI).

A seed law was passed in 1972 and revised in 1977. It is based on the British Plant Varieties and Seeds Act of 1964 and concentrates on control measures for seed quality. The law gives the government strong powers for controlling seed imports (Chapter 5) and includes articles on plant variety protection. Plant breeders' rights have not yet been included.

"Kenya Seed" is a brand name highly reputed in neighbouring countries: exports are an important cash earner for the company. Production of Basic Seed is concentrated on the KSC Elgon Downs Seed farm. Certified Seed is produced mainly by contract growers, the ADC taking an important share (Ndogwa et al., 1985). The harvested crops are transported to Seed Dryers Ltd., a subsidiary of KSC. With the exception of imported vegetables, the KSC has a monopoly within the country with regard to most crop seeds although foreign investors, such as Cargill and Pioneer, are eager to enter the maize seed market. The reputation of the company is illustrated by the extensive use of its trial grounds (by foreign companies such as VanderHave), for 'winter-multiplication' and crossing programmes for the development of maize hybrids for the European market.

Despite KSC's company structure, the national government is very influential in its running (through the parastatal ADC and the political ties with KGGCU). The government is aware of the economic importance of a healthy seed industry for the farming community and for national food security. It provides a certain level of protection, e.g. barriers for imports of seed, free access to results of national research, subsidies on seed security stocks, and the operation of a certification service (which charges for its services).
Table 7.2  Kenya-bred maize hybrids and varieties produced in 1993

<table>
<thead>
<tr>
<th>Name</th>
<th>Year of release</th>
<th>Type</th>
<th>Parents</th>
<th>Days to silk</th>
<th>Seed type</th>
<th>Yield, bags/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High altitude (1500-2100 m), high potential zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H611</td>
<td>1964</td>
<td>var. cross</td>
<td>KSII, Ec 573</td>
<td>113</td>
<td>flint</td>
<td>74.13</td>
</tr>
<tr>
<td>H612</td>
<td>1966</td>
<td>top-cross</td>
<td>s.c. x Ec 573</td>
<td>105</td>
<td>flint</td>
<td>74.13</td>
</tr>
<tr>
<td>H613</td>
<td>1972</td>
<td>top-cross</td>
<td>F G x Ec 573</td>
<td>112</td>
<td>flint-like</td>
<td>74.13</td>
</tr>
<tr>
<td>H614</td>
<td>1976</td>
<td>top-cross</td>
<td>A F x Ec 573</td>
<td>108</td>
<td>dent</td>
<td>79.07</td>
</tr>
<tr>
<td>H625</td>
<td>1981</td>
<td>double-cross</td>
<td>A F 3093 x 2050</td>
<td>104</td>
<td>dent</td>
<td>84.02</td>
</tr>
<tr>
<td>H626</td>
<td>1989</td>
<td>double-cross</td>
<td>A 1064 x 3093 x 4082</td>
<td>108</td>
<td>dent</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium altitude (1000-1700 m), high potential zone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H622</td>
<td>1985</td>
<td>double-cross</td>
<td>ADF G</td>
<td>110</td>
<td>intermed.</td>
<td>54.36</td>
</tr>
<tr>
<td>H632</td>
<td>1964</td>
<td>3-way cross</td>
<td>AFG</td>
<td>110</td>
<td>flint-like</td>
<td>59.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium altitude, medium potential area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H511</td>
<td>1968</td>
<td>var. cross</td>
<td>Embu 11, Embu 12</td>
<td>91</td>
<td>intermed.</td>
<td>39.54</td>
</tr>
<tr>
<td>H512</td>
<td>1970</td>
<td>top-cross</td>
<td>511, SHS2</td>
<td>96</td>
<td>intermed.</td>
<td>39.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Katumani Comp. B</td>
<td>1967</td>
<td>composite</td>
<td>local</td>
<td>75</td>
<td>semi-dent</td>
<td>29.65</td>
</tr>
<tr>
<td>Makuueni Comp.</td>
<td>1986</td>
<td>composite</td>
<td>local-French</td>
<td>70</td>
<td>flint</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low altitude coastal areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coast Comp.</td>
<td>1974</td>
<td>composite</td>
<td>local</td>
<td>104</td>
<td>intermed.</td>
<td>34.59</td>
</tr>
<tr>
<td>Pwani Hybrid</td>
<td>1986</td>
<td>var. cross</td>
<td>PS III, PS IV</td>
<td>90</td>
<td>dent</td>
<td>39.54</td>
</tr>
</tbody>
</table>

Notes: For the type of variety, see Chapter 3
Parents: inbred lines A, D, F, G, and 2084 are drawn from Kitale Synthetic material;
lines 2085, 3093, 4082 are drawn from Ecuador 573. SR52 is an old single cross hybrid from Zimbabwe (Zambia).
The hybrids 611, 612, and 613 are not widely grown anymore.
The parents of Pwani hybrid are actually based on Torpedo Planta Baja and ETO Blanco
Source: based on NSQORC, 1993.

Recent developments
Research on new hybrids is continuing but the remarkable results obtained with the hybrids in the mid '60s and '70s have not been obtained since. The release of hybrids in Kenya demonstrates well the progression from OP's, via varietal crosses and top-crosses to hybrids based on inbred lines for the high potential areas and on cheaper-to-produce composites and varietal crosses for the less-productive areas (Table 7.2 and Fig. 7.4).

Some hybrids in the recommended list are almost 30 years old, many hybrids have one or more parents in common, and only four hybrids or composites have been released in the past 15 years. Very few of the experimental varieties that were proposed in 1985 as replacements for the old ones (Mwenda, 1985), have actually survived the final tests. The result is that foreign seed companies see a potential market in Kenya for their own hybrids. One hybrid from Pioneer (X105A) has been released for the coastal areas after screening by KSC breeders. The Kenyan government, however, regards food crop seed as an extremely important factor in national food security and is hesitant to allow foreign multinationals to enter the market. It is argued that dependence on foreign-bred hybrids can mean political dependence. As a result of strict currency control measures, exports become necessary in order to finance the necessary imports (e.g. seed dressing chemicals). Competition with other suppliers in these international markets forces KSC to export its highest quality seeds.
This bears the risk that shortages on the national market can develop both with respect to quantities and quality. The monopoly on the local market may invite a reduced quality awareness: although well equipped for its task, the National Seed Quality Control Research Centre (NSQRC) may not be able to counteract such developments in a government-dominated seed company. Recent (1993) problems with seed quality in the Kenyan seed market (which may be due to the reasons above), are a cause for serious concern.

![Map of Kenya showing mean annual rainfall and sites of maize research centres](image)

**Figure 7.4** Mean annual rainfall in Kenya and sites of the maize research centres Kitale, Katumani, Embu and Mtwa pa (Mwenda, 1985)

The seed industry in Uganda

*The development of the Uganda Seed Project*

Uganda did not have many European settlers to influence its farming enterprises. Interest in improved seeds, therefore, emerged later than in Kenya. Research on maize concentrated on the development of improved open-pollinated varieties, resulting in the release in 1972 of 'Kawanda Composite 1' (KWCA) which is based on a wide variety of local and imported maize varieties (Kahwa & Kabere, 1985). In 1968, a seed production scheme was started within the Ministry of Agriculture, with assistance from Britain. Civil unrest throughout most of the 1970s and the first half of the 1980s, however, halted most research efforts. Donor assistance in seed projects resumed in the late 1970s and physiological seed quality gradually increased. Due to insufficient variety maintenance (Chapter 3), the important agronomic characteristics of KWCA had changed beyond tolerable limits. It was restored in 1989 and proved valuable until it was gradually replaced by 'Longe-1', an open-pollinated variety resulting from a cross between KWCA and a CIMMYT population that included ITA-based streak resistance.

Hybrid testing and development started only in 1991 and both the research system and the seed production programme are adapting to this new technology. Kenyan hybrids were imported legally and illegally throughout the troubled period. Most Kenyan hybrids, however, are adapted to higher elevations. This, and the fact that the fertiliser supply has been erratic, led to sub-optimal yields of these varieties.

Both plant breeding and seed production are the responsibility of the Ministry of Agriculture and are heavily dependent on donor assistance. In order to increase efficiency, the National Agricultural Research Organisation has been established, as a semi-governmental institution, with the responsibility to earn most of its own funds. The introduction of plant variety protection legislation is being considered in order to generate revenue through royalties. Also, the Uganda Seed Project (USP) will be privatised. The first step towards privatisation was the installation, in the mid-1980s, of a revolving fund which gave USP a certain level of independence from public administrative regulations. Regular capital injections, both by the government and donors, are still necessary because of the severe inflation (1980-87: 95% per annum, but much lower since then) and expanding business that calls for a larger working capital.

In the absence of efficient retail systems after the eviction of the traders of Asian origin in 1972, seed marketing was done through the cooperative movement and the agricultural extension service. Both organisations continually face cash flow problems that result in significant bad debts and further problems with the revolving fund (Chapter 3).

The lack of effective ways to distribute and sell seeds is considered one of the major obstacles to further expansion and commercialisation of the operations. The most important customers since 1988 have been the relief organisations which buy the seed in large quantities for distribution in war-stricken areas in the region. Poor seed harvests in Kenya and lower seed prices (in US$) due to liberalisation of currency controls, were important incentives to enter these export markets.

The national seed quality control operations are still integrated in the seed production organisation (Uganda Seed Project) and the whole is headed by one director. Though effective in early stages of seed industry development when a limited number of trained staff are required to operate the whole seed chain, this can result in problems when business increases and short-term commercial interests of the production and marketing units conflict with the integrity of quality-control staff.
Recent developments
Despite some administrative liberties, USP is still a fully public organisation but the government has accepted, in principle, its transformation into a private enterprise. A new donor-assisted project will 'rationalise' the seed industry and prepare USP for full privatisation.

To facilitate this and to legalise the operations of an independent national seed certification service, seed legislation is in preparation. A major aspect of the draft law is the establishment of a National Seed Industry Advisory Committee to initiate and monitor the developments.

In the mean time, large-scale farmers, the cooperative union and an American multinational seed company have announced a joint initiative to launch a commercial seed company independent of this public organisation. This created an important political debate and, despite the general open economic policy of the government, the company has not started yet because of political opposition and the financial problems of the Ugandan partners in this joint venture. Also, the enthusiasm of some of the partners waned, probably because particular sections of the draft seed law could be used by the government to oppose commercial interest in favour of the public competitor (USP). In this way a seed law intended to promote seed production (Chapter 5: seed legislation) may have had the opposite effect.

The seed industry in Malawi
The development of the National Seed Company of Malawi Ltd.
Malawi was long considered too small for an extensive national maize breeding programme. Until 1971, research concentrated on composites; Chitedze Composite A (local material) and Ukiriguru Composite A (UCA, from Tanzania) were released for low- and high-potential areas, respectively. Only one hybrid (LH11) had been released in the early days (Ngwira & Sibale, 1985).

Between 1968 and 1971, maize seed was distributed on an exchange basis. Since 1971, it has been sold at commercial prices. A national seed programme was established in 1973 and, in 1978, it was decided to establish the National Seed Company of Malawi (NSCM), to operate as a subsidiary of the national agricultural marketing parastatal, Agricultural Development and Marketing Corporation (ADMARC). This followed the release of three hybrids in 1977: CXH66, CXH74 and CXH43. A British development organisation, the Commonwealth Development Corporation (CDC), invested in the new company and supplied managerial staff from 1980 onwards. The company was fully commercial but was allocated a Government soft loan to invest in modern storage facilities (DANAGRO, 1988a). Marketing is done through ADMARC and official seed quality control by the public Seed Technology Unit.

Adoption of hybrid maize has been slow and erratic with sales of such seed below 5% of the country's total maize seed use throughout the 1980s (Cromwell, 1991). Smale (1990) describes the very complex adoption patterns, which do not concentrate only on expected yields but also on a range of consumption preferences and other characteristics.

An important property of the highly productive hybrids (both locally-developed and imported from Zambia and Zimbabwe) is that they are not flint types: i.e. are easily processed but also easily destroyed by insects during
Local maize populations are very flinty, i.e. they have a high proportion of very tough endosperm. The hybrids, therefore, are only of interest for economic farming near grain collection points (i.e. near the major cities). The many farmers who produce primarily for home consumption cannot grow these hybrids. Kydd (1989) described this lack of coordination between farmers’ preferences and research objectives and the resultant failure, throughout most of the 1980s, to commercialise the seed sector. Another major problem related to timeliness of seed supply (Cromwell, 1991).

In 1983, the sale of hybrid maize seeds stagnated at less than 2200 t, whereas the sales of composites tripled in the following three years to 1009 t. In a survey in 1984/85, only 7% of the area was planted to hybrids, a fact that illustrates the enormous potential for expansion (DANAGRO, 1988a). Despite these trends, the CDC management of the NSCM did increase economic returns. One of the methods was to cease seed production of most self-fertilizing and insignificant seed crops, and to concentrate on maize, tobacco and pasture crops for commercial farmers.

A Smallholder Seed Multiplication Scheme (SSMS) was initiated by the extension service to produce self-fertilizing crop seeds (especially groundnut) on a regional basis in order to fill the gaps. The SSMS has been a drain on public and ADMARC funds ever since.

Nevertheless, a considerable range of seeds was produced in 1988 (DANAGRO, 1988a): common bean (6)\(^1\), groundnut (2), maize hybrids (3), maize composites (2), Leucaena (2), pasture legumes (3, plus Rhizobium inoculants), grasses (4), sorghum (2), soybean (5), sunflower (4), wheat (4), tobacco (many) and vegetables (many repackaged).

Sales of maize seeds and the profitability of the NSCM may have been helped significantly by the government when maize seed subsidies (approx. 30%) were retained, though subsidies on other crop seeds were discontinued in 1987. In 1988, Cargill, a US-based multinational in grain trade and seed production (among many related activities) took over the CDC interest in NSCM. Official seed quality control remains a government undertaking.

Recent developments
The 1988 take-over of the NSCM by Cargill has rapidly changed the profile of the company;

- NSCM now closely monitors the distribution to ADMARC selling points, and private traders sell seed independently of the ADMARC network. This should reduce excessive carry-over stocks due to distribution inefficiencies. Such stocks amounted to an average of approximately 650 t of maize seed (plus 1000 t of other crop seeds) in the period 1983-1988 (Cromwell, 1991).

- ADMARC’s domination of the Board of NSCM resulted in a steady reduction of seed prices (in real terms) throughout the ‘80s. An upward trend is now visible, which should secure an improved internal efficiency.

- Salaries are now competitive with those in other sectors of private industry in Malawi - an important incentive for higher labour efficiency.

In order to maintain public support for its monopoly position in the market, NSCM will have to keep in mind the government’s national development objectives and the economic viability objectives of the Company. The future will show how Malawi will deal with this conflict.

The seed industry in Zambia

The development of ZAMSEED

Unlike the other countries in the region, Zambia, sparsely populated and rich in mineral resources, did not put much emphasis on the development of the agricultural sector. The Zambia Seed Producers Association, established by large-scale farmers in 1964, produced seed of two maize hybrids (SR52 and ZH1) which stemmed from the colonial period and the early days of independence. The Association was responsible for coordinating the importation of other seed and marketing was done through the parasatal, the National Agricultural Marketing Board (Nambord).

From 1979 onwards, the maize breeding programme received support from the Maize Research Institute, Zemun Polje, in Yugoslavia, (Ristanovic, 1989), from the Swedish International Development Agency (SIDA) and from the United States Agency for International Development (USAID). In 1980, a management contract with the commercial Swedish company Svalof AB was put into effect to upgrade the national seed industry with Swedish development assistance and, in 1981, the Zambia Seed Company (ZAMSEED) was established as a commercial company with the aim to ‘produce seed for the Zambian farmers at an affordable price’ (Moberg, 1989). Forty percent of the shares of ZAMSEED are controlled by ZIMCO, the Zambia Investment and Marketing Company (a parasatal) and 20% by the Zambia Cooperative Federation. As a result, the Government of Zambia has a strong influence but the bureaucratic side-effects are somewhat reduced through channeling the direct government interest through ZIMCO. Another 20% is held

\(^1\) refers to number of varieties
by the Zambia Seed Producers Association (ZSPA). The donor has influence through the shares (10%) of the development investment fund. The commitment of the executing agency of the management contract, Svalof AB, is assured through its 10% share-holding in the Company.

A new hybrid, MM752 (based on SR52) was released in 1983 after SR52 had degenerated to a large extent (when compared with the Zimbabwean 'SR52'). This was followed, in 1984, by a range of hybrids with different maturity periods: MM501, 502, 601, 603, 604, and 606 (Ristanovic & Gibson, 1985). Also, two open-pollinated varieties, MMV400 and MMV600, were released for the low- and high-rainfall areas, respectively. These account for less than 10% of the maize seed sales (Cromwell, 1992).

This influx of varieties increased the market potential of ZAMSEED but caused managerial problems and increased the cost of production (Chibasa, 1985). Although considerable emphasis is given to research-extension linkage through adaptive research planning teams, Sutherland (1989) argues that it is probable that much potentially-material never reaches the farmers because the main requirement for approval by the Variety Release Committee is the research stations' yield data and not farmers' preferences.

Production of maize seed is done by ZSPA members under contract with ZAMSEED. These are all large-scale farmers in the main maize growing areas of the country. In 1988, 2440 ha of seed was planted in the Central Province by 54 farmers, most of whom operate their own pre-cleaning machinery. Of this, 1800 ha was maize seed. Small farmers in the Central Province are involved in seed production of self-pollinating crops such as soybean and groundnut which do not require large isolation distances (Miyoba, 1989). Although produced by large-scale farmers, the majority (70%) of the maize seed is sold to small farmers (Kanungwe, 1989).

Marketing is done mainly through the provincial cooperative unions (which distribute the seed to their primary societies), but also through general traders (especially vegetable seeds). The aim is to have seed available for sale within walking distance of the farms, i.e. 10 km (Welving, 1983). ZAMSEED produces its own Breeder Seed (Cromwell, 1992). Compared with the National Seed Company of Malawi, ZAMSEED produces a wide range of agricultural and horticultural crop seeds.

The main problems encountered in marketing maize seed relate to the timeliness of supply. They include: late harvesting of seed crops; delayed payments to ZAMSEED by provincial cooperative unions; transport problems of ZAMSEED and/or the Unions; and inaccurate seed estimates (Harlande, 1989). Seed prices are fixed annually by the Government in close cooperation with ZAMSEED and other interested parties. With the exception of the 1987/88 season when ZAMSEED received eight million Kwacha in order to avoid seed price increases, there are no direct subsidies (Cromwell, 1992). There is a significant hidden subsidy, however, since ZAMSEED uses the varieties from the public research system.

Comparison of the four systems
The organisation of the maize seed industry in each of the African countries under review shows important differences, especially in donor and government involvement. Some of these differences relate to general historical developments such as the presence of large-scale farmers (Kenya, Zambia) and economic stability (lacking in Uganda for a long time). Another important factor is the efficiency of variety development. This was the major factor in seed industry development in Kenya in the early '60s, in Zambia in the early '80s, and in Malawi in the present decade. If the Kenyan research system fails to produce a range of new hybrids in the near future, this may be a sign of an impending decline of the KSC. The multinational (maize) seed companies appear to think that it is just a matter of time before countries like Kenya have to surrender to foreign-bred maize hybrids, thereby breaking down the monopolies.

Government involvement in seed production shows interesting differences in these four countries. Two are moving towards private-sector seed production, one is moving away from it, and one is stagnant. The trend in Malawi can be considered to be in line with present international development strategies as proclaimed by the World Bank. Initially a public unit, it became a parastatal, was commercialised with the assistance of a semi-commercial foreign organisation and, finally, was privatised in partnership with a multinational company.

ZAMSEED attracted a commercial foreign partner earlier and follows a smoother pathway with minority foreign share-holding and long-term donor involvement. Despite national and donor policies towards privatisation, the chances for the Uganda Seed Project to develop into a commercially-viable enterprise are likely to reduce, rather than increase, due to its heavy dependence on donor grants (Chapter 4).

The Kenya Seed Co. is a peculiar example of decreasing public interest and influence in the seed industry. Started as a private enterprise, it was taken over by public majority share-holding. This had the effect, after a number of years, of increased public influence on company management.

The size of public involvement has important effects on the style of operation and, possibly, the efficiency of the various seed producers. In Uganda, annual business losses are still accepted as the price that has to be paid to supply improved seed to the country's farming community: the product range is steadily expanding. Commercialisation in Malawi has led to a significant reduction in the number of crops of which meaningful quantities of seed are supplied. In Zambia and Kenya, the product range is still wide.
Government policies have a significant effect on the commercial sustainability of their national seed supply organisations. Support for maize breeding has had a major impact on the success of the Kenyan and Zambian seed industries. Subsidies on seeds appear to have had a negative effect on the Ugandan seed production infrastructure but retention of the subsidies in Malawi may have been decisive in the conversion of NSCM into a fully private enterprise. The involvement of the right donor agency at the right time appears to be one of the most important aspects determining the outcome of the development model. Grants (Uganda) or semi-commercial donor involvement to a large (Malawi) or small (Zambia) extent, may result in widely differing organisational structures.

The service to the farming community also differs with different models: the more commercial, the smaller the number of seed crops and the narrower the range of farmers supplied. Seed prices tend to increase during the initial stages of privatisation. Seed quality depends more on the level of competition, than on the ownership of the production organisation.

References in Section 7.3


7.4 Vegetable seed production in Southeast Asia

This section describes the emergence and operation of the East-West Seed Company Inc. in the Philippines, Thailand and Indonesia: the first large-scale vegetable seed company in the region. This case study, therefore, can serve as an illustration of the many considerations and actions that lead to the development of a viable seed enterprise in developing countries.

In 1982, ‘East-West’ was established in the Philippines as a joint venture between Dutch capital and business know-how, and local capital and expertise in vegetable farming and seed production. The company expanded to Thailand (1984) and Indonesia (1990), where affiliated joint ventures were formed with local counterparts. The initiation of these ventures was preceded by extensive market surveys from which were established priorities with regard to crops, market segments and research budgets. Also, decisions were made with regard to the basic infrastructure for business administration, research and seed production.

After discussing these steps in sequence, possible extrapolation from these experiences to other sectors and other regions, is considered here.

Market surveys

The situation with regard to vegetable seed supply in Southeast Asia in the early 1980s, could be characterised best by making a distinction between three categories of crops:

i. Indigenous crops of which seed can be multiplied easily. Examples include solanaceous species (eggplant, chilli, sweet pepper), cucurbits (cucumber, melons), legumes (cowpea, common bean), okra and leafy vegetables. Farmers normally save their own seed by collecting the last remaining fruits of a crop. Very few farmers produce seed of ‘selected varieties’ for sale. Local seed exchange and some selling in the towns and cities occur, especially, when vegetable prices are high. Seed is relatively cheap but unreliable with regard to the quantities and quality offered.

ii. Crops originating from temperate areas for which seed production is difficult or impossible under prevailing (climatic) conditions. Examples include white and Chinese cabbage, radish, carrot and lettuce. These are grown mainly in the tropical highlands. In most cases, imported seeds from industrialised countries are rather well adapted to these conditions (with respect to yield) but, often, they are susceptible to pests and diseases. Highland farmers, therefore, pay their share for the breeding work done in Japan, Taiwan and, to a lesser extent, the USA and the Netherlands, and get only relatively (l) well-adapted varieties. Seed quality is not always reliable and quantities and timeliness of supply can be affected by import (and currency) regulations. The seed prices are high compared with those in the previous class.

iii. The crops of (ii) above, but grown in the lowland tropics of the region. Varieties bred for temperate conditions are not adapted to such a climate and seed is not supplied by the reputable companies operating in that market. Instead, the suppliers for this group are normally traders, in Hong Kong, Singapore and Bangkok, who purchase bulk seed from any source at the lowest prices possible. This bulk seed of unknown origin and identity (and often of dubious quality), is the only source for lowland farmers. In a few cases only, farmers have been able to grow seed themselves. Examples are carrot and white cabbage for which Indonesian farmers developed their own selections.

In this context, the East-West Company set itself the task of ensuring a stable supply of qualitatively reliable seed at a reasonable price. ‘Obviously the biggest and most urgent task lies in the area of lowland grown vegetable crops.’ (East-West, 1994, company information)

After classifying the crops, potential competitors were identified as follows:

- internationally-operating seed companies based in industrialised countries (mainly highland crops, and watermelon);
- internationally-operating businesses (exotic crops for lowland cultivation);
• public seed enterprises and small local seed companies (indigenous crops); and
• self supporting farmers (indigenous crops).

For the lowland crops, it was predicted that competition from the small seed companies and farm-saved seed producers would be met by the supply of high quality seeds of adapted varieties. In addition, public institutions working in the field of vegetables were not considered a threat because of their lack of exposure to market information which results in ineffective breeding programmes. Also, in contrast with seed production of some field crops (e.g. rice), their knowledge of vegetable seed production and marketing was too limited to produce significant results.

Lack of serious competition was one of the major reasons for concentrating on these lowland vegetables. Other considerations were the technical aspects such as crop acreage, seasonality, crop economics and the ability of the seed to remain viable in storage under ambient conditions. The apparent lack of competition implied that there was no seed-marketing infrastructure and farmers had no experience of using purchased seed. Market development for these crop seeds is more difficult and time consuming than for seeds that are commonly bought and for which an existing market has to be conquered through supplying a better quality at an acceptable price.

Business infrastructure

The 'joint venture' organisational structure was chosen for technical, practical and legal reasons. Foreign expertise on business management and research organisation could thus be combined with local expertise on vegetable cultivation. Local contacts and knowledge about markets and government infrastructure were deemed necessary for the success of a commercial venture. Moreover, legal regulations in some countries make it difficult or impossible for a foreign company to operate independently.

East-West recognised that effective local seed industry development is only possible through a complete involvement in the local market, hence its decentralised set-up.

Variety development

The basis of variety development at East-West, is local germplasm. Selection within landraces can quickly yield interesting varieties. Also, landraces include old introductions that have developed into 'local varieties', often with a somewhat degenerated appearance but remarkably well adapted to local conditions. Foreign material is useful, though, as a source of additional characteristics such as specific disease resistances.

In the absence of plant variety protection legislation a strong emphasis was put on the development of hybrids which should secure a fair return on investment in research. Initially, however, hybrid development is very time consuming compared with breeding of open-pollinated varieties. In the initial phase, therefore, the company produced mainly open-pollinated varieties in order to establish a market for the brand name. A great commercial success was not expected from these early varieties, but for a number of crops, such as yardlong bean and kangkung (Ipomoea aquatica), farmers do appear to buy fresh seed very regularly. Bulk sales of these seeds now appear to be quite noteworthy.

Most hybrids are selected under local conditions of 'good farm management' without the large-scale use of additional input expenses. Others are selected for specific conditions, such as off-season production, which can increase the farmers' profits.

Often, in order to check for disease and pest resistances, less pesticide is used in trials than would be used in normal farm practice. Testing under truly marginal conditions is not done, because poor farmers cannot take the risk that is always linked with the use of a new variety. They have to 'play safe' which is why this market segment is very difficult to penetrate.

In addition to the 'biological protection' offered by hybrids, they have a number of other advantages over open-pollinated varieties. Hybrid vigour can produce significantly higher yields and better quality. For breeding companies, hybrids are interesting because they can more rapidly 'absorb' new characteristics (e.g. a disease resistance) since a single good breeding line with the characteristic can be used to produce a number of new hybrids without the need for large back-crossing programmes.

Candidate varieties are always tested on-farm before release. The farmers' comments on the new variety are taken into account in any decision to release commercially. These trials, moreover, serve as an essential source of information for the continuous review of breeding goals and priorities. To some extent, the results of the breeding process are shared among the three East-West affiliates. Limitations to this cooperation among East-West companies relate to local preferences and the general lack of adaptation of varieties in different climatic and edaphic zones. Local testing, therefore, always precedes release.

During the first 12 years of its existence in the Philippines, East-West has released 64 varieties of different vegetable crops (19 of which are hybrids). In Indonesia, a total of 31 varieties (of which 10 are hybrids) have been released in four years.

Seed production

To produce seed of a variety involves two major steps: securing the basic seed supply (stockseed) and actual commercial seed production. Stockseed production remains under full Company control at its own farms and under its own strict supervision. Commercial seed production is done mainly through contract farmers under the direct supervision of Company-employed production supervisors. The Indonesian branch of East-West had approximately 1200 contract growers in 1994. For hybrid seed crops, the
contract plot size is 500-1000 square meters; for beans and open-pollinated varieties of other crops, experienced seed farmers are given up to two hectares. This method allows for flexible production planning and reduced investments by the company. Strict supervision assures the production of seed that meets the company's quality standards. The quality of the seed produced in this way is high; less than 5% of the seed lots have to be rejected due to a germination percentage below 85%. For cabbages and radish, the germination percentage is commonly beyond 95%.

An additional result of this strategy is that it serves as a competitive source of income for the selected seed farmers. Basic Seed is supplied free of charge and inputs are advanced by the Company. The seed is bought at a fixed price, after germination and purity testing at the Company's laboratory.

Lessons learned
It has been proved that it is possible to develop a purely commercial seed enterprise in developing countries. The case of East-West Seed Company Inc. demonstrates well the preconditions and strategies necessary for seed industry development. The main issue is that, in any truly commercial strategy, the marketing aspects are of primary importance. In the initial stages of the company, the 'market pull' is more important than the 'research push'. Such a market approach limits the crop range to those crops with which an advantage can be attained over competitors such as importers and farmers. This comparative advantage can be in seed quality characteristics (genetic, physiological, physical, sanitary), or in reliability of supply. Another major issue is the important involvement of local commercial and technical expertise in a commercial seed enterprise with the foreign management input from international networks.

The East West case is not presented here to imply that such a development can be copied exactly with other crops or in other countries. The vegetable seed market is different from the field crops seed market with respect to a different volume/value ratio of the seed and, obviously, the final product.

Highly-intensive vegetable production generally requires a considerable investment in external inputs and labour. The seed costs, therefore, are only a small percentage of the total cash investment in the crop, even when seed prices are rather high. This is different from the situation with most field crops where seed is the major, or only, cash investment.

A disadvantage of vegetable seed production is the small and scattered market. In general, each farmer produces small quantities of vegetables. Even with specialised vegetable farming, requirements are for small amounts of seed, spread over a number of crops and varieties within crops, for specific purposes and markets. The result is that vegetable seed enterprises need a relatively large area in order to operate successfully. East-West started in the Philippines, a relatively large and densely-populated country with, traditionally, a significant and diverse vegetable consumption. Increasing the scale of operation to neighbouring countries further strengthened the economic basis of the company. It would be much more difficult, however, to repeat such a development exercise in the smaller countries of West Africa, for example, because the diets have less vegetable content and the economies (and purchasing power of the farmers) are less developed.

Another major difference is that, in most countries, extensive national breeding programmes and well-defined variety release procedures exist for field crops. These factors influence the analysis of possible competitors and, in some cases, the time frame between breeding and actual seed production. Although East-West has shown that hybrids are not strictly necessary for initial commercialisation of the seed industry, it is expected that they are very important for a continuation of the success of the company. In self-fertilizing field crops, where hybrids cannot be produced economically, successful commercialisation will be much more difficult. Commercialisation of seed production is more likely in (semi) cross-fertilizing crops such as maize, sunflower and sorghum where hybrids can be produced on a large scale. Even plant variety protection may not be a sufficient guarantee for commercial success in self-fertilizing field crops such as cereals and pulses where seed production coincides with food (grain) production. The option for on-farm seed production minimises the margins for the seed producer, and commercial success is only possible when a quick turnover of varieties can be obtained.

Maize seeds are not normally produced in vegetable cultivation, so knowledge of the production of quality seed is less widespread than for cereals and leguminous field crops.
1. Glossary of terms, abbreviations and acronyms

The definitions in this glossary refer to terms as they are commonly used in the seed sector. The same terms may have slightly different meanings in another context.

adapability the capability (of a variety) to perform well under given agro-ecological conditions. (see wide adaptation, yield stability).

AOSA American Association of Official Seed Analysts
AOSCA American Organisation of Seed Certification Associations of the United States of America (see Chapter 3)

blending the authorised mixing of seed lots.
buffer crop a crop that is planted around a seed field to protect the latter from foreign pollen.
centre of diversity geographical area where wide genetic diversity is found for particular crops and related species.

certification the assurance of varietal identity and varietal purity in seed production through generation control, inspection, and labelling.

Certified Seed a seed class in a certification scheme, produced from Foundation, Registered (AOSCA-system) or Basic (OECD-system) Seed, which is sold to farmers for crop production. In some cases it may be used to produce an additional generation of seed ('Certified, 2nd generation').

CGIAR Consultative Group on International Agricultural Research, being the umbrella organisation for a number of international agricultural research centres throughout the world.

cloning genetically homogeneous population of a vegetatively-propagated crop.

coevolution the evolution of plants, diseases, pests and weeds in interaction with each other.

composite variety a population of a cross-fertilizing crop resulting from a mixture of selected components (lines or populations).

conditioning all treatments of seeds from harvesting to planting, e.g. drying, storage, dressing and packaging.

contract grower a farmer who produces seed under contract to a seed organisation.

corruption inappropriate use of resources for individual gain, using the powers of one's position within the organisation.

cross-fertilizing crop a crop in which, under normal conditions, seeds are produced by intercrossing between plants within a population.

cultivar see 'variety'.

domestication the genetic adaptation of plants to the cultivation environment through selection.

double-cross hybrid a hybrid that results from a cross between two single cross hybrids.

DUS distinctness, uniformity (homogeneity) and stability, being the main requirements of a variety. DUS may be examined for variety registration for certification and/or for plant variety protection.

emasculated removal of potentially effective male organs (e.g. in hybrid production).

exchange control national government control of the free exportation and importation of currency.

FAO Food and Agriculture Organization of the United Nations

farm-saved seed seed sown at the same farm where it was harvested.

farmers' rights the proprietary rights that local farmers claim over genetic resources in landraces, similar to plant breeders' rights for modern varieties.

field inspection inspection of a seed field to check on isolation, seed crop management, varietal purity, etc.

formal seed supply system seed supply through an organised chain of events by specialised breeders, seed producers and marketing agents, and including certification.

GATT General Agreement on Tariffs and Trade

generation system a system whereby a seed lot can be traced back to a particular lot of Breeder (Pre-Basic) Seed. This forms the basis of a certification system.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>genetic diversity</td>
<td>the genetic variation within a plant species.</td>
</tr>
<tr>
<td>genetic erosion</td>
<td>the global loss of genetic diversity.</td>
</tr>
<tr>
<td>germination</td>
<td>(in seed testing) the percentage of seeds in a seed lot that develop within a given time into normal seedlings (see also viability, vigour).</td>
</tr>
<tr>
<td>germplasm</td>
<td>any plant material used for plant propagation and breeding, with emphasis on its genetic content.</td>
</tr>
<tr>
<td>Green Revolution</td>
<td>the large scale introduction of new farming technologies in the tropics in the 1960s and '70s, notably short straw rice and wheat in combination with fertilisers and pesticides.</td>
</tr>
<tr>
<td>heterogeneous</td>
<td>mixed, i.e. a population consisting of a mixture of genotypes.</td>
</tr>
<tr>
<td>heterosis</td>
<td>the superiority in performance of a hybrid compared with the mid-parent value of both parents. Often it is used for those cases where the hybrid is superior to both parents.</td>
</tr>
<tr>
<td>heterozygous</td>
<td>the combination of two different alleles on the same locus in one genotype.</td>
</tr>
<tr>
<td>hybrid</td>
<td>general: the progeny of a cross between two different parents. in seed production: a variety, for which seed is produced by controlled crossing of two different parents.</td>
</tr>
<tr>
<td>IARC</td>
<td>international agricultural research centre</td>
</tr>
<tr>
<td>inbred line</td>
<td>a genetically (nearly) homogeneous and (nearly) homozygous population, used for hybrid seed production.</td>
</tr>
<tr>
<td>in-situ preservation</td>
<td>preservation of genetic resources in the area where they occur naturally, i.e. in nature or in farmers' fields.</td>
</tr>
<tr>
<td>integrated seed supply system</td>
<td>combination of different aspects of the formal and the local seed supply, aimed at improvement of performance of both systems.</td>
</tr>
<tr>
<td>ISTA</td>
<td>International Seed Testing Association</td>
</tr>
<tr>
<td>joint venture</td>
<td>organisation of an enterprise whereby two or more major investors have a fixed interest (number of shares).</td>
</tr>
<tr>
<td>landrace</td>
<td>a local variety (distinct from other varieties), that is a mixture of genotypes resulting from biotic and non-biotic selection pressures in specific agro-ecological and socio-economic conditions.</td>
</tr>
<tr>
<td>mating system</td>
<td>the common way of combining male and female gametes in a species: e.g. self-fertilizers, (semi) cross-fertilizers.</td>
</tr>
<tr>
<td>mini-kit</td>
<td>a small quantity of different components of a new technology (e.g. seeds, fertiliser, pesticides, information leaflets), distributed to increase the adoption rate.</td>
</tr>
<tr>
<td>multi-line variety</td>
<td>a mixture of similar but not genetically identical pure lines of a self-fertilized crop, selected for improved performance.</td>
</tr>
<tr>
<td>multiplication factor</td>
<td>general: the number of seeds produced from one parent seed. in seed production: net seed yield per hectare (i.e. after seed cleaning and quality control), divided by the seed rate.</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
</tr>
<tr>
<td>on-farm research</td>
<td>a strategy of formal agricultural research, whereby farmers are involved in problem definition, setting of research priorities and testing and selection of technologies.</td>
</tr>
<tr>
<td>on-farm trials</td>
<td>the testing component of on-farm research.</td>
</tr>
<tr>
<td>parastatal</td>
<td>a company, operating under public administration rules and regulations and of which business losses are replenished by government.</td>
</tr>
<tr>
<td>phytosanitary control</td>
<td>measures to prevent the introduction of foreign plant diseases.</td>
</tr>
<tr>
<td>plant breeder's rights</td>
<td>the legal right of the originator of a modern crop variety within a plant variety protection system.</td>
</tr>
<tr>
<td>plant population</td>
<td>the number of plants per unit area expressed, for example, as plants per hectare.</td>
</tr>
<tr>
<td>plant variety protection</td>
<td>legal system of granting exclusive rights over a variety to its originator (breeder or discoverer). Note: not to be confused with 'plant protection' i.e. controlling diseases and pests.</td>
</tr>
<tr>
<td>post control</td>
<td>a final quality check on seed lots; used as an internal quality control of the seed quality control organisation.</td>
</tr>
<tr>
<td>pre-release multiplication</td>
<td>multiplication of seed of a new variety before it has been released officially, in order to prepare a stock of seed for further multiplication and sale as soon as the variety is released officially.</td>
</tr>
</tbody>
</table>
privatisation: transferring responsibility for a public organisation from the government to (private or public) investors.

product life cycle: in seed supply: the period during which a variety is adopted by farmers, becomes popular with many farmers and, gradually, is replaced by a competing (newer) variety.

product mix: in seed supply: the array of crops and varieties offered by a seed supplier.

pure-line variety: a genetically homogeneous and homozygous variety of a self-fertilizing crop.

quality-declared seed: seed in a quality control system, introduced by FAO, whereby 10% of the seed fields and lots are checked by an autonomous quality control agency and the remainder by the seed production organisation.

retail margin: the price differential offered to retailers either as the difference between fixed purchase and selling prices or the difference between purchase price and obtainable (free) selling price.

rogueing: removal of individual plants from a seed field (because they are off-type or diseased).

seed: generative or vegetative part of a plant that is used as propagation material.

seed aid programme: an emergency aid programme, supplying seed to disaster-affected farmers (see seed security programme).

seed board: regional or national committee to direct seed production and supply initiatives.

seed chain: the successive operations leading to seed supply, i.e., breeding, seed production, conditioning, marketing and quality control.

seed class: denomination of a generation within a certification scheme.

seed cleaning: removal of unwanted inert matter and seeds from a seed stock.

seed dressing: improvement of seed performance through chemical or other treatment of the seed coat.

seed policy: statement by a government to guide the development of seed supply.

self-fertilizing crop: a crop which under normal conditions produces seed as a result of self fertilization in at least 95% of the cases.

seed security programme: an aid programme designed to prevent the loss of seed by large numbers of farmers (see 'seed aid programme').

semi-cross-fertilizing crop: a crop where the majority of seeds are produced as a result of self fertilization but varying percentages of outcrossing may occur to a maximum of 50% depending on external conditions. In plant breeding they can be considered self-fertilizers (pure-line varieties), but in seed production as cross-fertilizers (large isolation requirement).

single-cross hybrid: the population of a cross-fertilizing crop resulting from open pollination within a mixture of two or more well defined and separately maintained (often inbred) parents.

synthetic variety: a hybrid resulting from a cross between an inbred and a single-cross hybrid.

threeway-cross hybrid: a hybrid resulting from a cross between an inbred line and a population or open-pollinated variety.

top-cross hybrid: a cross between two inbred lines.

UNCED: United Nations Conference on Environment and Development

UPOV: International Union for the Protection of New Varieties of Plants

varietal hybrid: a hybrid resulting from a cross between two open-pollinated populations.

variety: a population of plants, within a crop, which is distinct from other varieties, homogeneous taking into consideration the mating system of the crop and stable during repeated reproduction. Synonymous with cultivar.

variety maintenance: the conservation of the important features of a variety, by continuous selection.

variety release: the official approval of a variety for multiplication and distribution.

viability: the ability of a seed to germinate and to produce a normal seedling when conditions are good (see germination, vigour).

vigour: the properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions (see germination, viability).

VCU: value for cultivation and use; i.e. the combined values of a variety, as established by (field) trials.

wide adaptation: the ability of a variety to perform well in a variety of ecological areas and under a variety of farming methods.

yield stability: the buffering of ecological variation by the genetic constitution of a crop in a given place, under given general farming practices (see adaptation, wide adaptation).
## 2. Basic information on seed production of selected crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Planting rate (kg/ha)</th>
<th>Plant population (pl/ha x 100%)</th>
<th>Seed yield (t/ha)</th>
<th>Growing period (days)</th>
<th>Breeding system</th>
<th>m.f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice (upland)</td>
<td>20 - 40 (&lt; tr-pl)</td>
<td>500</td>
<td>1.5 - 5</td>
<td>90 - 210</td>
<td>s</td>
<td>50 - 175</td>
</tr>
<tr>
<td>Wheat</td>
<td>80 - 100</td>
<td>200</td>
<td>0.8 - 1.2</td>
<td>90 - 150</td>
<td>s</td>
<td>10</td>
</tr>
<tr>
<td>Maize</td>
<td>70 - 100</td>
<td>300</td>
<td>1.0 - 5</td>
<td>120 - 210</td>
<td>s</td>
<td>12 - 60</td>
</tr>
<tr>
<td>Sorghum</td>
<td>15 - 25</td>
<td>50</td>
<td>1.4 - 4</td>
<td>90 - 150</td>
<td>cw</td>
<td>70 - 200</td>
</tr>
<tr>
<td>Pearl millet</td>
<td>4 - 12</td>
<td>40 - 200</td>
<td>0.5 - 3.8</td>
<td>90 - 210</td>
<td>sc</td>
<td>47 - 60</td>
</tr>
<tr>
<td>Finger millet</td>
<td>5 - 10</td>
<td>110</td>
<td>0.6 - 2</td>
<td>60 - 90</td>
<td>cw</td>
<td>80 - 260</td>
</tr>
<tr>
<td>Cassava</td>
<td>10 - 20</td>
<td>220</td>
<td>0.6 - 2</td>
<td>60 - 90</td>
<td>s</td>
<td>40 - 130</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>20 000*</td>
<td>10 - 30</td>
<td>80 000*</td>
<td>365 - 730</td>
<td>v</td>
<td>3 - 4</td>
</tr>
<tr>
<td>Potato</td>
<td>35 000*</td>
<td>30 - 40</td>
<td>350 000*</td>
<td>90 - 180</td>
<td>v</td>
<td>5 - 15</td>
</tr>
<tr>
<td>Soybean</td>
<td>1.3 - 1.9</td>
<td>40</td>
<td>10 - 25</td>
<td>90 - 150</td>
<td>v</td>
<td>6 - 15</td>
</tr>
<tr>
<td>Chickpea</td>
<td>40 - 60</td>
<td>170 - 200</td>
<td>0.4 - 1.9</td>
<td>80 - 160</td>
<td>s</td>
<td>8 - 38</td>
</tr>
<tr>
<td>Groundnut</td>
<td>50 - 100</td>
<td>100 - 200</td>
<td>0.4 - 1.8</td>
<td>90 - 150</td>
<td>s</td>
<td>15 - 30</td>
</tr>
<tr>
<td>Sunflower</td>
<td>10</td>
<td>40 - 80</td>
<td>0.7 - 2</td>
<td>90 - 150</td>
<td>ci</td>
<td>70 - 200</td>
</tr>
<tr>
<td>Sesame</td>
<td>5 - 10</td>
<td>150 - 200</td>
<td>0.3 - 1.5</td>
<td>70</td>
<td>s</td>
<td>40 - 200</td>
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</tbody>
</table>

Notes:
Where ranges in yield are large, the higher yields generally are recorded from high input and irrigated production.
* = number of cuttings
Breeding systems: s = self pollinated, sc = semi-cross pollinated, cw = wind-pollinated, ci = insect-pollinated (according to Purseglove, 1977 a, b)
tr-pl = transplanted (rice).

Sources:
### 3 Crop names

<table>
<thead>
<tr>
<th>English</th>
<th>Botanical</th>
<th>French</th>
<th>Spanish</th>
<th>Portuguese</th>
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<tr>
<td>amaranth</td>
<td><em>Amaranthus</em> spp.</td>
<td>amarante</td>
<td>amaranto, bledo</td>
<td>caruru vermelho</td>
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<tr>
<td>barley</td>
<td><em>Hordeum vulgare</em> L.</td>
<td>orge</td>
<td>cevada</td>
<td>cebada</td>
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<tr>
<td>common bean</td>
<td><em>Phaseolus vulgaris</em> L.</td>
<td>haricot commun</td>
<td>judia comun</td>
<td>feijado</td>
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<tr>
<td>cabbage</td>
<td><em>Brassica oleracea</em> L.</td>
<td>chou vert</td>
<td>col berza</td>
<td>couve</td>
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<tr>
<td>carrot</td>
<td><em>Daucus carota</em> L.</td>
<td>carotte</td>
<td>zanahoria</td>
<td>cenoura</td>
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<td>cassava</td>
<td><em>Manihot esculenta</em> Crantz</td>
<td>manioc</td>
<td>yuca brava, manioca</td>
<td>mandioca</td>
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<tr>
<td>chickpea</td>
<td><em>Cicer arietinum</em> L.</td>
<td>pois chiche</td>
<td>garbanzo</td>
<td>gran de bica</td>
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<tr>
<td>chili/sweet pepper</td>
<td><em>Capsicum annuum</em></td>
<td>poivron, piment</td>
<td>pimiento</td>
<td>pimento</td>
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<tr>
<td>cowpea</td>
<td><em>Vigna unguiculata</em> (L.)</td>
<td>nciebe, haricot dolique</td>
<td>frijol arroz</td>
<td>feijado chicote</td>
</tr>
<tr>
<td>cucumber</td>
<td><em>Cucumis sativus</em> L.</td>
<td>concombre/cornichon</td>
<td>pepino</td>
<td>pepino</td>
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<tr>
<td>eggplant</td>
<td><em>Solanum melongena</em> L.</td>
<td>aubergine</td>
<td>berengena</td>
<td>beringela</td>
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<tr>
<td>finger millet</td>
<td><em>Eleusine coracana</em> (L.)</td>
<td>eleusine</td>
<td>miyo coracana</td>
<td>capim raxenim</td>
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<tr>
<td>foxtail millet</td>
<td><em>Setaria italic</em> (L.) Beauv.</td>
<td>millet des oiscaux</td>
<td>panizo comun</td>
<td>milho painco</td>
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<tr>
<td>green gram</td>
<td><em>Vigna radiata</em> (L.) Wilczek</td>
<td>amberigue</td>
<td>judia mung</td>
<td>ervilha de Jerusalem</td>
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<tr>
<td>groundnut/peanut</td>
<td><em>Arachis hypogaea</em> L.</td>
<td>arachide</td>
<td>cacahuete/mani</td>
<td>amendoim</td>
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<tr>
<td>lentil</td>
<td><em>Lens culinaris</em> Med.</td>
<td>lentille</td>
<td>lenteja</td>
<td>lentilha</td>
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<tr>
<td>lettuce</td>
<td><em>Lactuca sativa</em> L.</td>
<td>laitue</td>
<td>lechuga</td>
<td>alfalfa</td>
</tr>
<tr>
<td>maize/corn</td>
<td><em>Zea Mays</em> L.</td>
<td>maia</td>
<td>maiz</td>
<td>milho</td>
</tr>
<tr>
<td>melon</td>
<td><em>Cucurbita melo</em> L.</td>
<td>melon</td>
<td>melon</td>
<td>melao</td>
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<tr>
<td>oats</td>
<td><em>Avena sativa</em> L.</td>
<td>avoine</td>
<td>avena</td>
<td>aveia</td>
</tr>
<tr>
<td>okra/ladies finger</td>
<td><em>Abelmoschus esculentus</em> (L.) Moench.</td>
<td>gombo/okra</td>
<td>gombo/ocra</td>
<td>quiabo</td>
</tr>
<tr>
<td>onion</td>
<td><em>Allium cepa</em> L.</td>
<td>oignon</td>
<td>cebolla</td>
<td>cebola</td>
</tr>
<tr>
<td>pea</td>
<td><em>Pisum sativum</em> L.</td>
<td>pois</td>
<td>gaisante/arveja</td>
<td>ervilha</td>
</tr>
<tr>
<td>pearl/bulrush millet</td>
<td><em>Pennisetum americanum</em> (L.) Leekie</td>
<td>mil a chandelier/perle</td>
<td>mio perla/junco</td>
<td>milhete massango</td>
</tr>
<tr>
<td>pigeon pea/red gram</td>
<td><em>Cajanus cajan</em> (L.) Mill sp.</td>
<td>ambrevade</td>
<td>guando</td>
<td>guando</td>
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<tr>
<td>potato</td>
<td><em>Solanum tuberosum</em> L.</td>
<td>pomme de terre</td>
<td>patata/papa</td>
<td>batata</td>
</tr>
<tr>
<td>pumpkin</td>
<td><em>Cucurbita spp.</em></td>
<td>potiron</td>
<td>abobora menina</td>
<td>calabaza amarilla</td>
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<tr>
<td>radish</td>
<td><em>Raphanus sativus</em> L.</td>
<td>radis</td>
<td>rabano</td>
<td>rabanete</td>
</tr>
<tr>
<td>rice</td>
<td><em>Oryza</em> sativa L./O. glaberrima Steud.</td>
<td>riz</td>
<td>arroz</td>
<td>arroz</td>
</tr>
<tr>
<td>rye</td>
<td><em>Secale cereale</em> L.</td>
<td>seigle</td>
<td>centeno</td>
<td>centeio</td>
</tr>
<tr>
<td>sesame/benniseed</td>
<td><em>Sesamum indicum</em> L.</td>
<td>sesame</td>
<td>sesamo</td>
<td>gergelim</td>
</tr>
<tr>
<td>sorghum</td>
<td><em>Sorghum bicolor</em> (L.) Moench</td>
<td>sorgho, gros mil</td>
<td>sorgo</td>
<td>sorgo</td>
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<tr>
<td>soya bean/soybean</td>
<td><em>Glycine max</em> (L.) Merr.</td>
<td>soja</td>
<td>soja</td>
<td>soja</td>
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<tr>
<td>sunflower</td>
<td><em>Helianthus annuus</em> L.</td>
<td>tournesol</td>
<td>girassol</td>
<td>girassol</td>
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<tr>
<td>tomato</td>
<td><em>Lycopersicon esculentum</em> Mill.</td>
<td>tomate</td>
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<td>tomate</td>
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<tr>
<td>wheat</td>
<td><em>Triticum aestivum</em> L.</td>
<td>ble/froment</td>
<td>trigo candeal</td>
<td>trigo mole</td>
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<tr>
<td>yam</td>
<td><em>Dioscorea</em> spp.</td>
<td>yname</td>
<td>name/nome</td>
<td>inhame</td>
</tr>
</tbody>
</table>

*: botanical names are presented as used in the PROSEA Series (see References, Chapter 3)
4 Selected reference books

General

Crops

Processing and Storage
Linnett, B., 1986. Seed Processing in Australia. Queensland Dept of Primary Industries Information Series Q186008. QDPI, Brisbane
Quality control


Policy and legislation

Mooney, P.R., 1980. Seeds of the Earth. Inter Pares, Ottawa.

Genetic resources

5 Addresses

International organisations that deal with seeds

AOSA Association of Official Seed Analysts. c/o USDA National Seed Storage Laboratory, Colorado State University, Fort Collins CO 80523, USA.

AOSCA Association of Official Seed Certifying Agencies in North America and New Zealand, 3709 Hillsborough Street, Raleigh NC 27607, USA.

ASSINSEL Association Internationale des Selectionneurs Professionnels pour la Protection des Obtentions Vegetales, Chemin de Reposoir 5-7, 1260 Nyon, Switzerland.

CGIAR Consultative Group on International Agricultural Research, 1818 H Street NW, Washington DC 20433, USA.

EU (Commission of the) European Union, Rue de la Loi 100, 1049 Brussels, Belgium.

FAO Food and Agriculture Organisation of the United Nations, Seeds and Plant Genetic Resources Service, Via delle Terme di Caracalla, 00100 Rome, Italy.

FIS Federation Internationale du Commerce des Semences, Chemin de Reposoir, 1260 Nyon, Switzerland.

ISTA International Seed Testing Association, Reckenholz, Postfach 412, 8046 Zuerich, Switzerland.

OECD Organisation for Economic Co-operation and Development, Directorate for Food, Agriculture and Fisheries, 2 Rue Andre Pascal, 75775 Paris Cedex 16, France.

UPOV Union Internationale pour la Protection des Obtentions Vegetales, 3 Rue Andre Pascal, 75775 Paris Cedex 16, France.

World Bank Agricultural and Rural Development Department, 1818 H Street NW, Washington DC 20433, USA.

International research institutes with seed related research (CGIAR)

CIAT International Centre for Tropical Agriculture, Apdo Aereo 6713, Cali, Colombia.

CIFOR Center for International Forestry Research, Bogor, Indonesia.

CIMMYT International Centre for Maize and Wheat Improvement, Londres 40, Apdo Postal 6-541 Mexico DF.

CIP International Potato Center, Apdo 5969, Lima, Peru.

IPGRI International Plant Genetic Resources Institute, Via delle Sette Chiese 142, 00142 Rome, Italy.

ICARDA International Center for Agricultural Research in the Dry Areas, PO Box 5466, Aleppo, Syria.

ICRISAT International Centre for Research in Agro-Forestry, PO Box 30677 Nairobi, Kenya.

ICRISAT International Centre for Research in the Semi-Arid Tropics, Panancheri PO, Andhra Pradesh 502324, India.

IITA International Institute for Tropical Agriculture, PMB 5320, Ibadan, Nigeria.

ILRI International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia and PO Box 30709, Nairobi, Kenya.

INIBAP International Network for the Improvement of Banana and Plantain, Agropolis-Montpellier, Bat.7 - Boulevard de la Lironde, 34980 Montferrier sur Lez, France.

IRRI International Rice Research Institute, PO Box 933, Manilla, Philippines.


WARDA West African Rice Development Association, 01 BP 2551, Bouske, Ivory Coast.
Institutes with regular international training courses in seed technology

Bogor Agricultural University
CIRAD; Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement
DSE/ZEL
Danish Government Institute for Seed Pathology in Developing Countries
Edinburgh School of Agriculture
IAC: International Agricultural Centre
ICARDA (in conjunction with University of Jordan, Amman)
Instituto Agronomico Mediterraneo de Zaragoza
Maize Research Institute Zemun Polje
Massey University Seed Technology Centre
Mississippi State University
UPLB: University of the Philippines in Los Banos, Seed Technology Programme
Svalof AB
Zamorano University

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PO Box 89, 11081, Zemun, Serbia.
Palmerston North, New Zealand.
PO Box 5267, MS 39762, USA.
PO Box 430, Los Banos College, Laguna, Philippines.

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PO Box 93, Tegucigalpa, Honduras