Cowpea in evolving livestock systems

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Abstract

Demand for livestock products has been increasing through much of the semi-arid tropics and will likely continue to increase along with the use of purchased feedstuffs. As smallholder livestock systems evolve and become more market oriented, the type of diets fed to livestock may change and the importance of feed marketing may increase. Mixed crop–livestock systems are key to meeting this increasing livestock product demand and cowpea (*Vigna unguiculata* [L.] Walp.) fodder (haulms) is an important component of these systems in semi-arid regions of the tropics where its high nutritional quality allows it to be used as a supplement to livestock diets based on cereal stovers and other low-quality forages. Improving the nutritional quality of cowpea fodder for use by livestock is important to improving the productivity and profitability of these mixed farming systems. Legume fodders will remain an important part of changing livestock diets and the development of cowpea varieties that better feed both people and their farm animals will give farmers new and better choices for improving levels and efficiency of livestock production. Cowpea breeding programs have worked toward producing dual-purpose varieties that emphasize the production of grain and fodder since the late 1980s and have produced several that have become well accepted when tested on-farm. Systematic screening of cowpea genetic resources is important for advancing development of dual-purpose varieties. Involvement of cultivar release agencies and seed production programs are also important to advance the use of improved dual-purpose crop varieties.

Introduction

Cowpea (*Vigna unguiculata* [L.] Walp.) is an annual legume grown throughout the semi-arid tropics, where it is valued as both human and livestock food. It is drought tolerant, can be grown on relatively poor soils, and fixes nitrogen, thereby improving soil fertility. In addition to grain, cowpea can produce good yields of fodder for ruminant feeding systems. To effectively utilize cowpea as livestock feed, it is important to understand the systems of animal production and the changes occurring that will influence how cowpea is used as a feed resource now and in the future. Use of improved methods for screening crop germplasm, including screening for improved nutritional quality, can aid in rapid advancement in cowpea varieties that fit well into crop–livestock systems.

Global livestock systems

Livestock have traditionally been raised for a variety of purposes including meat, milk, fiber, draft power, and savings. Increasing human population densities and rising incomes throughout the world are creating an increase in global demand for livestock products. Poultry meat and eggs have been experiencing the largest increases in demand (Table 1), but demand for products from ruminant livestock has also increased. There is opportunity to increase production efficiency in smallholder systems to allow participation in these increasing livestock product markets. Understanding both the process of intensification and technological options are important to promoting this participation.

Table 1. Production and trends for livestock production in the developing world,

Products	Total production 1992 (million t)	2002	Annual growth of total production 1992–2002 (%)
Beef and buffalo	22	31	3.2
Pig meat	37	57	4.4
Poultry meat	19	40	7.6
Sheep and goats	6	9	3.6
All meat	87	139	4.8
Milk	170	251	4.0
Eggs	22	41	6.5

Source: Rae and Nayga 2010.

Types of livestock raised by smallholder farmers and their associated production systems are greatly influenced by the feed resources available, with ruminant livestock able to utilize low quality roughage in grazed or confined settings. Areas with lower population densities and less arable lands are used to produce ruminants in grazing or pastoral systems, whereas more densely populated areas and those with arable lands under more intensive farming may develop confined feeding systems for both ruminant and non-ruminant livestock.

As regions of the world experience increasing population densities and land-use changes, livestock farming systems also shift to more intensified systems, that is, systems with higher external inputs. Livestock systems follow a somewhat predictable course as they intensify (Erenstein and Thorpe 2010) and understanding this process can improve targeting of technical options to increase efficiency of production. Under extensive conditions, where livestock graze rangeland or standing crop residues there may be little dietary supplementation practiced. As farming becomes more intensive and land resources more scarce, livestock may no longer have access to free grazing and farmers may shift to a system of cut-and-carry for feeding. This process allows more control over livestock diets and improves the ability to target feeding toward specific markets, whether for meat or milk.

Mixed systems, those producing both crops and livestock on the same farm, are a major source of livestock products. Globally, these mixed crop–livestock farming systems account for about 40% of the beef, 12% of the lamb and mutton, and 88% of the milk produced (Table 2; de Haan et al. 2010). In the developing world, these systems contribute to the production of 65% of the beef, 75% of the milk, and 55% of the lamb and mutton (Herrero et al. 2009). These systems also house a significant proportion of the world's population, especially smallholder farmers in regions of sub-Saharan Africa and Asia. Sale of livestock products can be a substantial portion of the income in some systems and also contributes to farming activities through draft power and provision of manure for soil fertility.

Table 2. Global livestock population and production in different systems for 2001–2003.

	Livestock production systems			
	Grazing	Rainfed mixed	Irrigated mixed	Industrial
Livestock population (million head)				
Cattle and buffaloes	406	641	450	29.0
Sheep and goats	590	632	546	9.0
Animal products (million tons)				
Total beef	14.6	29.3	12.9	3.9
Total mutton	3.8	4.0	4.0	0.1
Total milk	71.5	319.2	203.7	0.0

Source: de Haan et al. 2010.

Cowpea supplementation of ruminant diets

Crop residues make up a major component of livestock diets in mixed crop–livestock systems and, therefore, improving the use and nutritional quality of crop residues is important to enhancing farm productivity and profitability. Cowpea is an important component in mixed systems in semi-arid regions of the tropics and is valued for its potential to produce high levels of fodder for livestock in addition to grain for people.

A number of studies have been conducted to evaluate additions of cowpea fodder as a supplement to poorer quality hay and stover. Cowpea haulm addition improves nutrient supply and growth of livestock over the use of low quality forages alone but degree of weight change varies relative to total nutrient supply (Schlecht et al. 1995;Ngwa and Tawah 2002; Baloyi et al. 2006; Baloyi et al 2008). It should be noted that only a limited number of studies report the specific variety of cowpea used and animal response has been reported to differ with variety and its associated forage quality (Anele et al. 2010). Singh et al. (2003) reported higher weight gain in rams supplemented with the cowpea haulms of variety IT90K-277-2 compared to Dan Ila and Akinlade et al. (2005) reported increased milk yield in cows supplemented with cowpea haulms of variety IT96D-716 compared to 994-DP.

Residues of cereal crops are generally nutritionally inadequate to produce high yields of meat and milk. The greater nutritional quality of legume residues allows them to be used as a supplement to livestock diets based on cereal stover and other low-quality forage. One benefit of the use of cowpea and other legume fodders as a supplement is the provision of nitrogen to the rumen microbes, allowing them to improve utilization of the low quality forage. Energy intake is improved by both the addition of a higher energy feed (cowpea) and by increasing the availability of energy through increased digestibility of the lower quality forage. At some level of supplementation, nitrogen becomes surplus to available carbohydrates for microbial growth and additional nitrogen may be wasted. Therefore, it is important to optimize ruminant diets to maximize digestibility with minimum nitrogen wastage.

An example of this diet development is found in the study of Koralagama et al. (2008) who fed either 150 or 300 g/d haulms from either a forage- or dual purpose-type cowpea to Ethiopian sheep fed a basal diet of maize stover. Dietary nitrogen was increased by cowpea haulm addition and higher levels of cowpea feeding resulted in higher nitrogen intakes. Total feed intake increased with increasing levels of cowpea supplementation but, while diet digestibility was greater for diets containing cowpea haulms, it did not differ between the levels or types of cowpea. The results of the study indicated that nitrogen level for the lower levels of cowpea supplementation likely matched the needs of the rumen microbes for the type of carbohydrate found (fiber) in these diets. This is also supported by increased urinary nitrogen excretion in sheep fed cowpea at 300 g/d compared to 150 g/day, indicating that some nitrogen was likely leaving the rumen as ammonia nitrogen rather than being incorporated into microbial cells. Sheep in these studies gained about between 32 and 51 g/d when supplemented with cowpea. Chakeredza et al. (2002) found a 22.7% increase in microbial protein supply when cowpea haulms were added to a diet of maize stover which also illustrates how cowpea improves nitrogen supply for rumen microbes.

This hypothesis supports the results of the study reported by Singh et al. (2003), in which additions of about 200 g cowpea haulms were shown to be the most economically viable level in feeding systems based on cereal stover compared to feeding either 400 or 600 g of supplemental haulms. Although increasing amounts of cowpea in a diet based on sorghum stover resulted in increased gains, the amount of increase diminished with each subsequent increase, resulting in the lowest level of cowpea addition (200 g) being the most economical. This is also consistent with economic theory that the economically optimal supplementation level will always be somewhat less than the maximum biological efficiency from supplementation (Torrell and Rimbey 2010).

Maintenance intake is the level of feed intake that provides adequate nutrients for bodily functions such as respiration and digestion, without excess nutrients for use in weight gain or other non-essential functions. To support productive functions such as growth, milk production, and pregnancy, it is necessary to increase intake above maintenance. To provide options for optimal mixes of sorghum stover and cowpea haulms, Savadogo et al. (2000) fed 21-kg rams varied levels of cowpea haulms in addition to sorghum stover at levels that allowed selective consumption of stover. This allowed rams to select between sorghum leaf and stem, a factor that affects digestibility and intake of the diet. The researchers then calculated the varied amounts of cowpea haulms needed to reach various levels of maintenance intake up to two times maintenance. For example, maintenance intake was reached with 61 g organic matter (OM)/ $kg^{0.75}$ body weight (BW) for sorghum stover and an additional of 48 g cowpea OM/$kg^{0.75}$ BW was required to reach two times maintenance. The studies showed the wide range in stover–cowpea combinations that could result in the same level of maintenance intake. This approach provides information useful for mixing diets relative to targeted production goals and can be used in combination with feed price information to develop diets producing the best economic returns.

The use of low-quality forage, such as cereal stover, as the major feedstuff in ruminant diets can limit both energy density and intake. Supplementation of low-quality forage with legumes will increase diet utilization to some extent, but for higher levels of production, increased dietary energy density through the use of higher quality forage and some grain may become of interest to livestock producers. Legume fodder such as cowpea can remain an important part of these higher energy diets. Table 3 shows the theoretical response to cowpea haulm addition given different types of diets, based on either cereal stover or cowpea haulms. These calculations are based upon responses of typical breeds in the US and the response of other breeds may differ.

Table 3. Expected average daily gains for a 40 kg ram consuming varied combinations of cereal stover, legume forage, grain, and by-product feeds. Calculations based on NRC 1985.

	Diet				
	1	2	3	4	5
Cereal stover, kg	0.8	1.0	–	0.7	0.7
Cowpea haulm, kg	–	0.6	1.5	0.7	0.7
Wheat bran, kg	–	–	0.3	0.3	–
Millet grain, kg	–	–	–	–	0.3
CP, %	3.8	8.7	17.0	11.4	10.8
N relative to requirements	Inadequate	Adequate for rumen function	Excess	Adequate for growth	Adequate for growth
Expected ADG, g/d	–8	90	155	137	161

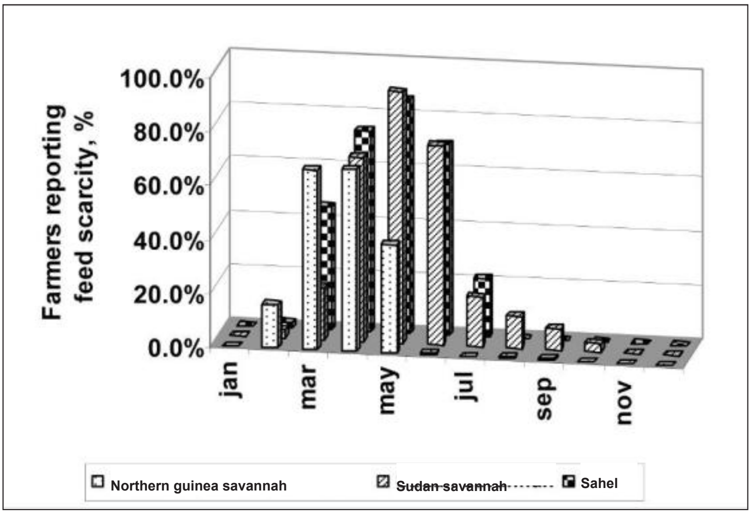

Figure 1. Percent of farmers in three agroecological zones of northern Nigeria experiencing feed scarcity for sheep during selected months of the year. Values for cattle and goats differ slightly but relation among months is similar.

Many combinations of low-quality forage and cowpea haulms can be made to promote efficient production and there is no one diet that will work in all settings. Changing prices of both feed and livestock will affect the choice. Economic evaluation of the system should include the relative costs of feeds and price received for livestock of greater weight and body condition. In many locations livestock are sold on a per animal basis with visual evaluation of quality and not by weight. As measures of livestock value change in a system, with increased payment based on actual animal performance, the relative value of feed resources may change. As this occurs, an improved understanding of nutritional requirements and expected average daily gains of indigenous livestock can improve the accuracy of these estimates.

Movement to higher quality feeding systems needs to be approached with caution as feed shortages exist in many regions during part of the year. Livestock farmers in three agroecological zones of Nigeria reported periods of feed scarcity during the dry season (March to June or July, depending upon the zone; Figure 1). It is important to develop practical diets for fattening programs in the context of the full year's feed supply needs. Using large quantities of cowpea as the basal forage in fattening programs may limit its availability for use as a supplement for other livestock and may negatively impact overall herd efficiency. This aspect of year-round feeding management needs to consider increasing availability of supplemental feeds, including cowpea haulms, sold in markets.

Cowpea haulms can be found for sale in feed markets in many areas where cowpea is grown. Feed marketing exists at many levels, with very informal selling of residues directly off the farms to nearby livestock farmers, marketing of bundled residues along roadsides and in markets, to more formalized selling of mixed concentrates. Farmers in mixed crop–livestock systems in many areas may be well positioned to respond to increasing livestock product demand, but doing so may require improved feeding strategies which will increasingly need to be linked to markets for feeds and supporting information. As feed markets expand, additional actors may be added to cowpea and fodder value chains and it will be important to recognize and support the additional links in the chain.

Farmers often use or sell cowpea haulms soon after harvest because nutritional quality is not retained as well as that of other legume alternatives, such as groundnut (*Arachis hypogaea* L.). In the monitoring of informal feed markets near Kano, Nigeria, we have found availability of cowpea haulms to be more limited than that of groundnut, with cowpea generally only available from January through April, whereas groundnut haulms are available all year (Figure 2). The reasons for this difference are multifaceted and have not been thoroughly studied but relate, in part, to decreased quality during storage. Improved storage methods to decrease leaf loss after harvest could improve the market value of cowpea haulms over a longer period of the year.

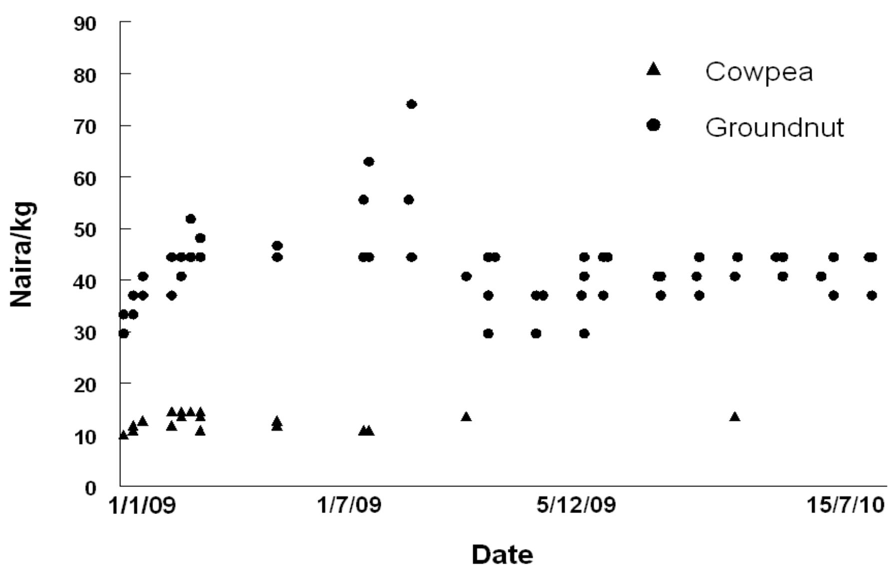

Figure 2. Price and availability of small units of cowpea and groundnut haulms in five informal feed markets within or near Kano, Nigeria. Price for those graded as "green and leafy" or "green and stemmy" only, no sun- or rain-damaged haulms included. (One US dollar is equal to about 151 Naira at time of study).

Table 4. The changing composition of feedstuffs in the developing world.

	Total utilization M tons)		% total change
	1992	2002	1992–2002
Cereals	176.1	235.1	33.5
Maize	120.0	177.4	47.8
Other coarse grains	37.8	40.5	7.1
Starchy roots	93.3	114.2	22.4
Oilcrops	5.8	9.9	70.7
Soybean	1.7	4.4	158.8
Cottonseed	3.2	3.0	–6.3

Source: Rae and Nayga 2010.

Livestock systems reaching the highest levels of intensification may begin to show an increasing reliance on forage grown specifically as livestock feed. Cowpea can also play a role in these systems and forage-type cowpeas have been tested and used for both grazing and hay production. Much work was conducted in Australia as early as the 1950s and comparisons have been made to other forage legumes in areas of Nigeria (Tarawali et al. 1997) and India (Relwani et al. 1970). More recently, researchers in Florida (Foster et al. 2009) have tested cowpea forage as a supplement for sheep fed bahiagrass hay compared to other legume hays or soybean meal. Cowpea hay had lower crude protein concentrations than annual (*Archis hypogaea* (L.)) and perennial (*Arachis glabrata* Benth.) groundnut hays resulting in lower nitrogen intake and retention and dry matter digestibility compared to the groundnut hays, however, dry-matter intake and nitrogen intake and retention were greater than for non-supplemented controls. Further development to improve forage cowpeas for specific systems can improve their utilization as supplemental feeds for livestock.

At some level of intensification and increased market opportunity, farmers may choose to begin including grains in the diets of fattening livestock (Erenstein and Thorpe 2010). As this occurs, other dietary components tend to shift as the balance of needed carbohydrates and nitrogen changes. Table 4 shows the increasing use of non-forage feed resources for livestock feeding that has occurred in the developing world in recent years. Much of this is driven by monogastric (poultry and swine) feeding, but increases in grain use are also occurring in ruminant systems.

In surveys conducted in northern Nigeria associated with the Sub-Saharan Africa Challenge Program, we found that among farmers fattening rams, 25.6 and 21.8% were feeding sorghum and millet grain, respectively, to their rams in the Sahel agroecological zone. In the Sudan savanna zone, livestock farmers were feeding sorghum grain, cowpea seed, and soybean seed (24.2, 21.8, and 6.5% of respondents, respectively). None of the ram fatteners surveyed in the northern Guinea savanna reported grain use, but the actual reason for this difference is unclear. Some of the grains fed in these systems are likely cracked, broken or poor quality seeds and, therefore, less valuable as market grain. Access to both input and output markets, differences in crop diversity, and household size, among other factors, can all affect these decisions to sell or feed grain.

Cowpea grains are high in protein, making them valuable as both a protein and an energy source to ruminant diets. Singh et al. (2006) found positive results in intake, weight gain, and nitrogen retention when cowpea grains were used as a substitute for groundnut cake in diets based on dry mixed grasses fed to lambs. A study reported by Paduano et al. (1995) suggested similar responses to cowpea grain addition. However, wool growth was decreased at the highest level of cowpea inclusion, suggesting that protease inhibitors in the cowpea could be affecting amino acid availability. Further evaluation of cowpea grain feed quality may become important if grain feeding of livestock increases in areas where it is produced.

Livestock feeds and nutrient cycling

Livestock are often kept in mixed systems to provide manure as a soil amendment, improving soil fertility and crop yields where inorganic fertilizer use is marginal. Feed quality affects nitrogen and phosphorus quality of manure with dietary legume addition having the potential to improve manure quality. Table 3 shows how inclusion of cowpea and other feeds could be expected to alter dietary nitrogen relative to the needs of rumen microbes and the ruminant animal itself. The addition of small levels of cowpea to a diet of cereal stover could be expected to meet the needs of rumen microbes to improve digestion and intake as discussed previously. Completely replacing cereal stover with cowpea haulms as the forage source, in combination with wheat bran, a fairly accessible by-product feed, increases dietary nitrogen well above the needs of both the rumen microbes and the animal's needs for lean tissue growth. This diet would likely result in excess nitrogen excretion by the animal. However, because of the relatively high availability of nitrogen, it is expected that much would be excreted in the urine rather than faeces as observed in the study reported by Koralagama et al. (2008). This urinary nitrogen is relatively soluble and volatile and much would likely be lost unless technologies were adopted to capture it for later use. Combining cereal stover with legumes and grains and or by-product feeds (see diet 4 and 5, Table 3) creates diets which match nitrogen needs for growth while supplying energy for good rates of gain and likely avoiding excessive nitrogen that might lead to negative environmental consequences.

Changing livestock systems require that nutrient cycling be evaluated at several scales. Manipulating diets to improve nitrogen content relative to crop needs may be beneficial within a closed crop–livestock farming system. However, increasing demand for livestock products is also driving an increase in urban and peri-urban livestock production. In these systems, separation of crop and livestock production can create imbalances in nutrients in the environment. Several studies have recently reported on the inefficient use of nutrients within the urban livestock system in Niamey, Niger (Graefe et al. 2008; Diogo et al. 2010). As cowpea haulms are increasingly shifted to markets, where they may be fed to livestock not located on farm ground, nutrients may be in excess in some areas but depleted in others. This is a key research-for-development challenge in cowpea systems in West Africa in relation to the dynamics of livestock systems.

Dual-purpose cowpea

Cowpea works well as a dual-purpose crop and yields of grain and fodder can both be increased through breeding without one decreasing the yield of the other. A collaborative program between IITA and ILRI, which was started in the 1980s to evaluate and develop dual-purpose varieties led to development of several lines that have become well accepted when tested on-farm (Okike et al. 2002, Kamara et al. 2010). It is likely however, that farmers prefer to use several varieties of cowpea and dual-purpose varieties may not meet the sole needs of farmers (Okike et al. 2002, Tarawali et al. 2003).

The use of molecular markers in plant breeding can speed the selection of varieties with favorable traits. Additionally, screening tools that can rapidly assess the nutritional quality of forages can aid the evaluation process. Near-infrared reflectance spectroscopy (NIRS) can be used for fast and inexpensive analysis of small quantities of plant biomass from many accessions and has been used in screening for nutritional value of a variety of crop residues (Melchinger et al. 1986, Blümmel et al. 2007).

We evaluated nutritional quality of a genetically diverse panel of 157 cowpea accessions planted in Minjibir, Kano, Nigeria (12º08 'N, 8º40 'E) in 2009 and harvested when 95% of the plants reached maturity. Fertilizer (N-P-K) was applied before planting, four applications of insecticide were used to control major insect pests and two hand weedings were performed to control weeds. Seed and fodder yields were recorded at harvest after drying. Fodder samples were analyzed for quality traits using a FOSS near infrared reflectance spectrophotometer at ILRI, Hyderabad, India.

Yields ranged from 37.7 to 1546.8 kg/ha for seed and 584.5 to 7431.5 kg/ha for fodder (Figure 3). The correlation between seed and fodder yield was 0.27 (P = 0.0007). This indicates that selection for forage yield will not negatively impact grain yield for cowpea. Some of the accessions producing the greatest amount of seed also produced the largest amounts of fodder.

Haulm N ranged from 0.97 to 2.42 g/kg DM and averaged 1.76 (S.D. = 0.299). The higher quality fodders may be the most useful to supply supplemental nitrogen to ruminant diets, whereas the lower quality fodders may be useful as basal forages. Seed yield and haulm nitrogen content were weakly negatively correlated (r = –0.41, P < 0.0001; Figure 3). Metabolizable energy (ME) content ranged from 7.8 to 9.2 MJ/kg, which spans a range from high to low quality fodder for livestock. Average ME was 8.46 MJ/kg (S.D. = 0.25).
We found small, but positive correlations between fodder yield and days to 95% pod maturity (r = 0.237, P = 0.003). Tyagi et al. (1978) suggested that dry matter yields were positively correlated with days to flower in varieties tested in India. Correlations may be lower than expected because of the large grouping of accessions reaching 95% pod maturity at 60 to 80 days (Figure 4). The average day to 95% pod maturity was 76 (S.D. 12). The measure of days to maturity is an important characteristic for drought avoidance in cowpea (Singh et al. 2003). Days to 95% pod maturity was also mildly correlated to haulm quality.

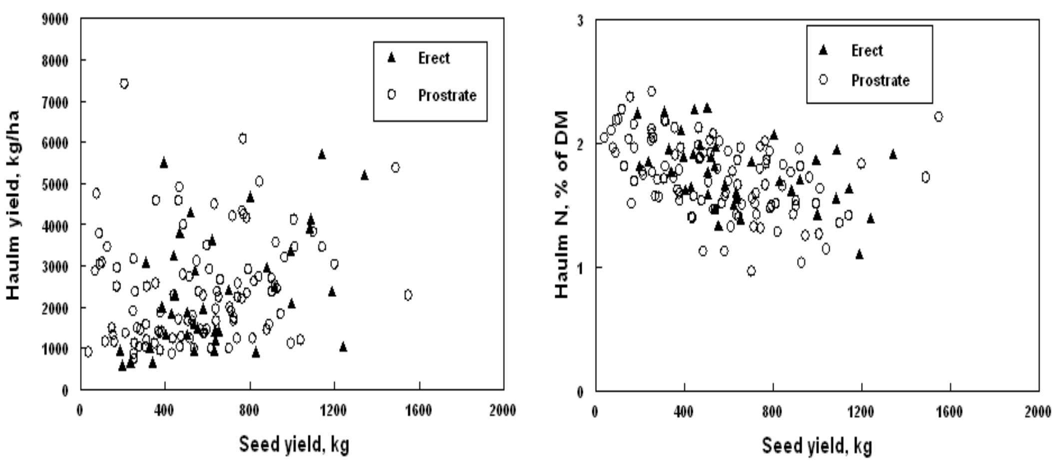

Figure 3. Data from 157 cowpea accessions grown in Kano, Nigeria. Left panel: Seed and fodder yield, kg/ha. Overall r = 0.27, *P* = 0.0007; Right panel: Haulm nitrogen (N) content and seed yield, overall r = –0.41, *P* < 0.0001. The grouping "erect" included those characterized as acute-erect, erect, and semi-erect; the grouping "prostrate" included those characterized as intermediate, semi-prostrate, and prostrate.

This correlation was 0.330 ($P < 0.0001$) for nitrogen and 0.453 ($P < 0.0001$) for metabolizable energy (ME; Figure 4).

It has been suggested that cowpea varieties with semi spreading growth would be ideal for dual-purpose use (Singh et al. 2003). To evaluate this, we divided varieties into two categories depending on their growth habits as listed in the IITA genebank database where they are characterized as having one of seven growth habits: acute-erect, erect, semi-erect, intermediate, semi-prostrate, prostrate, and climbing. We combined data for the first (n = 40) and second three (n = 107) categories, deleting the climbing habit, and reanalyzed trait correlations. Although correlations and associated probability values changed somewhat due to changes in the number of values used, the only correlation that changed substantially was that for the relation between metabolizable energy and days to 95% pod maturity for the erect types. This correlation was 0.092 ($P = 0.574$) compared to 0.496 ($P < 0.001$) for the prostrate grouping. These data indicate that selection for dual-purpose varieties need not be limited to more semi-prostrate or prostrate varieties.

The materials used in this study are part of a genebank reference collection for which additional characterization has been or is being conducted. Significant variation exists within cowpea germplasm collections to further advance development of dual-purpose varieties. These data can be used to further refine selection of cowpea accessions for their utility as a dual-purpose crop and in conjunction with genotypic information to identify those linkage group regions associated with food and feed use. Such information will be useful in marker-assisted selection of cowpea breeding lines with these desirable traits.

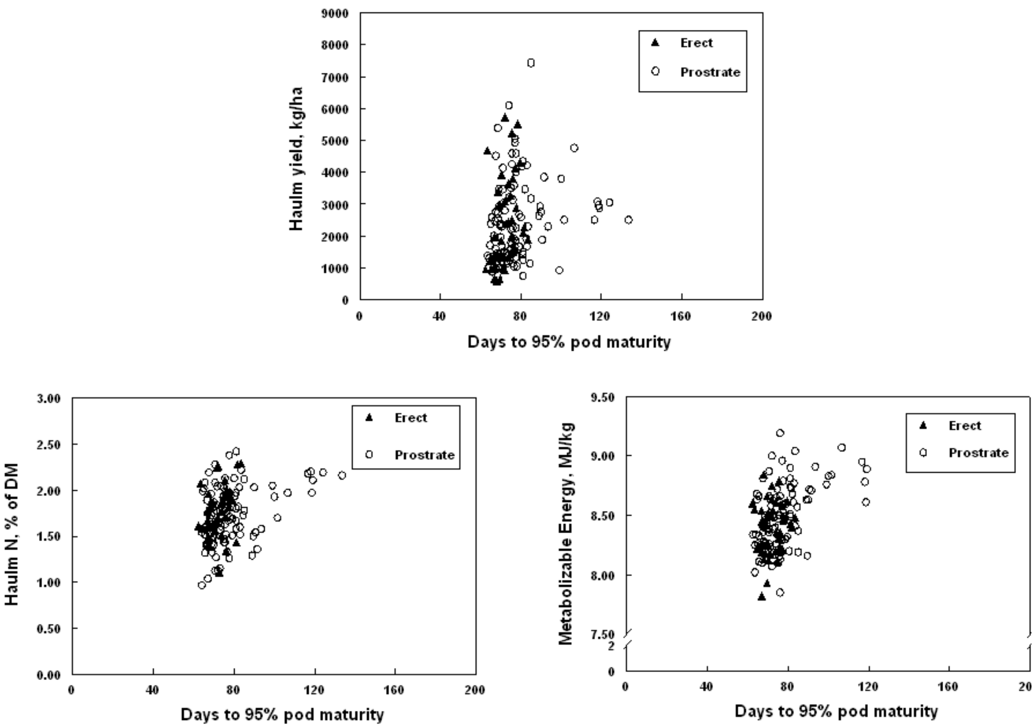

Figure 4. Relation of fodder yield and nutritional quality to days to 95% pod maturity for 157 cowpea accessions grown near Kano, Nigeria. For fodder yield and days to pod maturity, overall r = 0.237, $P = 0.003$; for haulm N (% of dry matter) and days to pod maturity overall r = 0.330, $P < 0.0001$; for haulm metabolizable energy (ME, MJ/kg) content and days to 95% pod maturity overall r = 0.453, $P < 0.0001$. The grouping "erect" included those characterized as acute-erect, erect and semi-erect; the grouping "prostrate" included those characterized as intermediate, semi-prostrate and prostrate.

Conclusions

Further actions to promote dissemination of dual-purpose cowpea varieties will be needed to support adoption of new varieties. Inclusion of dual-purpose traits, such as high fodder yield in dual-purpose lines and quality can be included in variety release criteria. It is important for plant breeders to intimate variety release and registration agencies with the benefits of dual-purpose varieties, especially farmers involved in crop-livestock systems. Seed systems also need to be supported to allow farmers access to varieties that best suit their needs.

Cowpea has served as a dual-purpose crop throughout the semi-arid tropics. As livestock systems change, a continued, and perhaps, increasing role for cowpea can be envisioned. Consideration of the current and potential uses of cowpea as livestock feed in cowpea research and development programs will assist in preparing for a bright future for cowpea farmers.

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