EFFECT OF PLANT DENSITY, SPATIAL ARRANGEMENT, AND PLANT TYPE ON WEED CONTROL IN COWPEA AND SOYBEAN

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Abstract. Since herbicides are not widely used in cowpea and soybean at the present time, cultural and manual methods are important means of weed control in the tropics. Field experiments were conducted at Ibadan (in western Nigeria) to evaluate the effects of plant density, spatial arrangement, and plant type on weed control in cowpea (Vigna unguiculata L.) and soybean (Glycine max L.) (Merr.). On the average, weeds reduced seed yield of cowpea by about 46% and of soybean by about 34%. In addition, weeds present during pod ripening of soybean significantly reduced the percentage of smooth, clean seed, and germination of soybean when maturation occurred during wet weather. Increasing the plant density or reducing row spacing at a given density reduced weed weight and yield loss in soybean. Some cowpea and soybean cultivars were more competitive against weeds than others. Plant characters associated with the competitive ability against weeds were plant height, leaf shape and size, and leaf area index. Weed weight was negatively correlated with leaf area index ($r = -0.67$).

INTRODUCTION

Cowpea is the third most important food legume in the lowland tropics after peanuts (Arachis hypogea L.) and pigeon pea (Cajanus cajan Mill sp.). Soybean is an important food legume in Asia but a recent introduction to many countries in Africa (Rachie and Roberts, 1974). Average yield losses in cowpea and soybean due to weed competition have been reported to be about 50% in Nigeria and India (Bhan, 1975; Moody, 1974), whereas in the United States the average yield losses in soybean are about 17% (Vega et. al., 1970).

Several studies conducted in the United States showed that soybean cultivars exhibited variable response to weed competition (McWhorter and Barrentine, 1975; McWhorter and Hartwig, 1972). The latest-maturing and tallest-growing cultivars were generally the most competitive and showed the smallest yield reduction due to weeds. Recent studies conducted in the Phillipines have indicated that some cowpea cultivars are also more competitive against weeds than others, and the competitive ability of these cultivars appeared to be related to both the canopy height and leaf area index (IRRI, 1976). However, these more competitive cultivars often displayed a lower yield potential than less competitive cultivars.

Narrow row spacings have been reported to be more effective in suppressing weed growth than wide row spacings (Kust and Smith, 1969; Wax and Pendleton, 1968). As row spacing decreases, fewer interrow

cultivations and lower rates of herbicides are needed to achieve comparable weed suppression (Burnside, 1972). However, cowpea and soybean cannot be grown at extremely narrow spacings as this can result in yield loss due to lodging and/or interplant competition. Furthermore, use of narrow spacings can make interrow cultivation impractical, although this is not a problem for the majority of small farmers in the tropics because they do not have the equipment for it.

The studies reported here were designed to evaluate the effect of plant density, spatial arrangement, and plant type on seed yield and quality of cowpea and soybean. The cultivars were selected on the basis of the differences in leaf shape and size, number and angle of branches, and canopy/plant height. The main objective is to establish some principles on how to improve the efficiency of cultural weed control method by manipulating plant spacing and type.

MATERIALS AND METHODS

Field experiments were conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The major weeds found at IITA are three species of grasses (Eleusine indica, Digitaria horizontalis, and Brachiaria deflexa) and seven species of broadleaved weeds (Amaranthus spinosus, Euphorbia heterophylla, Commelina benghalensis, Physalis angulata, Phyllanthus amarus, Talinum triangulare, and Synedrella nodiflora). The proportions of grassy and broadleaved weeds varied from one field to another depending on the cropping history of the plots used in the experiment.

Cowpea studies. The first experiment was conducted during the first season 1976 to evaluate the effects of row spacing and number of hoeweedings of four cultivars of cowpea differing in their growth habit. The treatments consisted of two spacings (20 by 50 cm vs. 20 by 100 cm); three hoeweedings (none, one weeding at 15 days after planting and two weedings at 15 and 30 days after planting) and four cultivars. These cultivars were erect, vigorous and determinate TVx 1836-19E; semi-erect, leafy, broadleaf, indeterminate type VITA-1; semi-erect, strap leaf, indeterminate type TVx 33-1C; and semi-prostrate, broadleaf, indeterminate type VITA-5. The design of the experiment was split-split plot with the number of hoeweedings as the main plots, spacings as subplots and cultivars as sub-subplots. Each treatment was replicated 4 times. The plot size was 3 x 5 m.

The second experiment was conducted in the first season 1977 to assess the effect of weeding methods on four cultivars of cowpea. The weeding methods were: (1) weed free; (2) one hoeweeding at 15 DAP; (3) hoeweeding between the rows only leaving the weeds within 20 cm around the plants untouched; (4) hoeweeding within 20 cm around the plants leaving the weeds between rows untouched; (5) mowing the weeds with a cutlass to 5 cm above ground; and (6) unweeded control. The four cultivars used were similar to those in the first experiment except TVx 1836-19E which was replaced with a less leafy and more disease-resistant cultivar ER-1 (TVx 2869-P 2-2). The experimental design was split plot with cultivars as main plots and weeding methods as subplots. Each treatment was replicated four times. The plot size was 3 by 5 m and the plant spacings were 20 by 75 cm for smaller cultivars ER-1 and VITA-5 and 20 by 100 cm for the larger cultivars VITA-1 and TVx 33-1G.

The two experiments were fertilized with 30 kg N and 30 kg P/ha and sprayed weekly with insecticide Nuvacron at the rate of 0.5 kg/ha to control insect pests.

Soybean studies. The first experiment was conducted in the first season 1977 to assess the effects of row spacing and hoeweedings on seed yield and quality of three soybean cultivars, differing in plant height and growth duration. The row spacings were 5 by 37.5 cm and 5 by 75 cm. The weed control treatments consisted of no weeding and two weedings at 15 and 30 DAP. The three cultivars selected were short and early growth duration Williams, medium height and duration Bossier, and tall and long duration Jupiter. The experimental design was split plot with cultivars as main plots and factorial combinations of weedings and spacings as subplots. Each treatment was replicated four times. The plot size was 3 by 5 m.

The second experiment was conducted in the second season 1977 to study the effects of plant density, spatial arrangement and hoeweeding on seed yield and quality of three cultivars, Williams, Bossier and Jupiter. The spacing treatments consisted of a factorial combination of two plant densities (133, 333 and 266, 666 plants/ha) and three spatial arrangements. Each plot was either weeded once at 30 days after planting, or unweeded throughout. The experimental design was split-split plot with cultivars as main plots, hoeweedings as subplots and spacings as sub-subplots. The treatments

were replicated three times. The plot size was 3 by 5 m.

The soybean seeds in all the three experiments were inoculated with commercial "Nitragin" inoculant just before planting. The fields were fertilized with 30 kg N and 30 kg P/ha. The soybeans were sprayed weekly with Nuvacron at 0.5 kg/ha to control pests.

Ten plants were sampled from each plot at 50-55 days after planting to determine leaf area index and dry matter production. Cowpea pods were picked at weekly intervals as soon as they were ripe in order to determine the yield. Soybean was harvested only once when about 95 percent of its pods had ripened. Seed quality of soybean was evaluated by taking a random sample of 100 seeds from each plot. The seeds were classified according to their appearance (purple stained, cracked, wrinkled and smooth clean seeds) and germination tests were carried out at a temperature of 25^{o}C. The weight of weeds from each plot was determined at the end of harvest on the basis of oven-dry weight at 100^{o}C for 24 hours.

RESULTS AND DISCUSSION

Effect of row spacing and number of weedings on cowpea. The weed growth in this experiment was uniform and vigorous. Without hoeweeding the weed weight reached up to 6 ton/ha at harvest, resulting in complete failure of the cowpea. Increasing the number of hoeweedings to two and reducing the row spacing from 100 cm to 50 cm significantly reduced weed weight (Table 1). Among four cultivars, VITA-1 had the lowest weed weight and VITA-5 the highest. Seed yields of the cowpeas were significantly increased by the number of hoeweedings but not by the row spacing (Table 1). Among the four cultivars, VITA-5 had the highest percentage of yield losses (70%) followed by TVx 33-1G (48%) and TVx 1836-19E (24%). VITA-5 had the lowest canopy height (53 cm) but had comparable leaf area index with TVx 1836-19E and TVx 33-1G. VITA-1 had the highest leaf area index (3.55). TVx 1836-19E and TVx 33-1G had the tallest canopy height (72 cm). However, the yield performance of VITA-1 was poor, probably owing to its sensitivity to daylength in the first season.

Effect of weeding methods on cowpea. In this experiment, weed emergence was slower and the weed density lower than in the previous experiment. Without weeding, the dry weed weight was only about 1 ton/ha, and this quantity of weeds did not cause complete yield

losses as in the previous experiment. Under these conditions, one hoeweeding at 15 DAP was sufficient to give comparable yields as the weed-free check (Table 2). Removing weeds between rows only resulted in a yield reduction of 19% and those within the rows of 41%, indicating that the weeds within the rows caused more damage to cowpea than those between rows although the latter could cause a significant yield reduction. Mowing the weeds to 5 cm above ground resulted in a yield reduction of 27% compared to a yield reduction of 40% in the unweeded plots.

Among the four cultivars, VITA-1 and VITA-5 had significantly lower weed weight and lower percentage of yield losses than ER-1 and TVx 33-1G (Table 3). The yield reductions due to weeds were 25% for VITA-1, 33% for VITA-5, 46% for ER-1 and 54% for TVx 33-1G. The competitive ability of VITA-1 and VITA-5 was associated with their high leaf area index and canopy height. Although TVx 33-1G was the tallest, it had relatively low LAI. Furthermore, its strap leaves allowed more light to penetrate to the ground, thus reducing its effectiveness to suppress weed growth.

Effect of plant density and weeding on soybean. The short, early cultivar Williams had the lowest leaf area index and the highest weed weight compared with Bossier and Jupiter (Table 4). The tall, late-maturing Jupiter had the highest leaf area index and the lowest weed weight. The differences among cultivars in weed weight and leaf area index were highly significant. Decreasing row spacing from 75 to 37.5 cm significantly reduced weed weight in all the cultivars. Row spacing had no effect on seed yield when the weeds were properly controlled, but increased the yields of soybean up to 142% in weedy plots. Among the cultivars, Williams had the highest percentage of yield loss (47%), followed by Bossier (35%) and Jupiter (28%). But the seed yield of Jupiter was extremely low due to severe moisture stress during pod filling stage when the rain ceased at about 85 days after planting.

Weeds not only reduced seed yield but also seed quality and germination of soybean (Table 4). The effect of weeds on seed quality and germination was noticeable only in Williams and Bossier which matured during the rainy season, but not in Jupiter which matured during the dry, sunny weather. Apparently, the weeds around soybean plants altered the microclimate around the pods since the relative humidity and seed moisture content were higher in weedy plots than

in weed-free plots at a given time during the day. This was reflected in the higher percentage of purple-stained seed and lower percentage germination of seed obtained from weedy plots.

Effect of plant density and spatial arrangement on soybean. In general, increasing the plant density from 133,333 to 266,666 plants/ha significantly reduced weed weight and increased seed yield. However, at either plant density, the 75 cm row spacing had higher percentage of yield losses due to weeds than the 37.5 or 25 cm row spacings. This indicates that narrow row spacings were more effective in suppressing weed growth than wide row spacings, even when the plant density was not altered (Table 5). Among the three cultivars, Williams was less competitive than the taller cultivars Bossier and Jupiter (Table 6). Williams had higher weed weight than Bossier and Jupiter appeared to be associated with their high leaf area index. Although significantly reduced the germination percentage Williams seeds, they did not affect seed quality of either Jupiter or Bossier, possibly because weed growth in these cultivars was not heavy and the cultivars matured at the end of rainy season (Table 6). Williams ripened during the rainy season, about two to four weeks before Bossier and Jupiter.

On the average, seed yields of cowpea and soybean were reduced by about 46% and 34% respectively when weeds were not removed. The presence of weeds at harvest also reduced the seed quality and viability of soybean when pod maturity occurred during the rainy season. This factor is important because seed viability is one of the major problems of soybean in the tropics (Nangju et al., 1975). In cowpea, weeds have also been found to increase the seed damage by pests, probably because the weeds reduced the effectiveness of insecticide application and provided a favorable environment for the insects (Moody and Whitney, 1974).

Philips (1964) estimated that it took 10 to 12 man-days/ha to hoe-weed in annual crops having light weed growth and 22 to 27 man-days/ha when the weed growth was heavy. Since hoeweeding is the most common method of weed control in annual crops in the tropics, emphasis should be given to finding ways to reduce the time taken to carry out this operation. However, cultivars and spacing should also be selected with care so that they can minimize the effect of weeds on seed yield and quality. The cultivars selected should not only be high-yielding and disease and pest-resistant but

also competitive against weeds. These results and others (IRRI, 1976; Mr. Whorter and Hartwig, 1972) indicated that the competitive cultivars of cowpea and soybean were characterized by high stature and/or high leaf area index. These two parameters are, however, greatly influenced by management practices such as fertilizers, plant density, soil moisture, and insect control. For this reason, the competitive ability of a given variety can be increased by improved management practices.

In cowpea, the competitive ability against weeds might also be influenced by the shape and size of leaves, since in one experiment the strap leaf TVx 33-1G was found to be less competitive compared with other cultivars which had similar leaf area index. With regard to plant spacing, both the number of plants per unit area and the spatial arrangements of the plants had a significant effect in suppressing weed growth. A square arrangement was more effective in reducing weed growth than a rectangular one. These results suggest that the conventional row spacing of either 75 or 100 cm is less efficient than narrow rows for small farmers who rely mainly on hoe-weeding as a means of weed control.

REFERENCES

Ashby, O.G., and R.K. Pfeiffer. 1956.
Weeds -- A Limiting Factor in Agriculture. World Crops 8: 227-229.

Bhan, V.M. 1975.
Weeds Associated with Soybeans and Their Control.

Burnside, O.C. 1972.
Tolerance of Soybean Cultivars to Weed Competition and Herbicides. Weed Sci. 20: 294-297.

Hammerton, J.L. 1976.
Soybean Weed Control Problems in the Tropics and Subtropics. In: L.D. Hill (Ed.), World Soybean Research. Interstate Printers, Inc., Danville, Illinois, p. 404-410.

International Rice Research Institute (IRRI). 1976.
Annual Report for 1976. Los Banos, Philippines.

Kust, C.A., and R.R. Smith. 1969.
Interaction of Linuron and Row Spacing for Control of Yellow Foxtail and Barnyard Grass in Soybeans. Weed Sci. 17: 489-491.

McWhorter, C.G., and W.L. Barrentine. 1975.
Cocklebur Control in Soybeans as Affected by Cultivars, Seeding Rates and Methods of Weed Control. Weed Sci. 23: 386-390.

McWhorter, C.G. and E.E. Hartwig. 1972.
Competition of Johnsongrass and Cocklebur with Six Soybean Varieties. Weed Sci. 20: 56-59.

Moody, K. 1974.
Weeds and Shifting Cultivation. F.A.O. Soils Bull. 24: 155-166.

Moody, K., and W.K. Whitney. 1974.
The Effect of Weed and Insect Damage to Developing Cowpea and Soybean Seeds. Proc. Nigerian Weed Science Group Meeting, Nsukka, 15-18 July 1974.

Nangju, D., H.C. Wien and T.P. Singh. 1975.
Some Factors Affecting Soybean Viability and Emergence in the Lowland Tropics. In: L.D. Hill (Ed.). World Soybean Research Conference. Interstate Printers Inc., Danville, Illinois.

Philips, T.A. 1964.
An Agricultural Notebook. Longmans, Nigeria. 248 p.

Rachie, K.O. and L.M. Roberts. 1974.
Grain Legume of the Lowland Tropics. Advances in Agron. 26: 1-132.

Riveros, G. 1976.
Importance of Weed Control in Tropical Soybeans. In: R.M. Goodman (Ed.), Expanding the Use of Soybeans. INTSOY series No. 10., University of Illinois, Urbana, p. 65-68.

Vega, M.R., E.C. Paller, Jr. and M.T. Madrid, Jr. 1970.
Weed Control in Soybeans. Paper presented at a workshop of legume workers. April 6, 1970. Los Banos, Philippines.

Wax, L.M. and J.W. Pendleton. 1968.
Effects of Row Spacing on Weed Control in Soybeans. Weed Sci. 16: 462-465.

Table 1. Effect of weeding and spacing on weed weight and seed yield of cowpea, 1976.

Cultivar	Weed weight (kg/ha)*				Seed yield (kg/ha)				% yield** losses
	W0	W1	W2	Mean	W0	W1	W2	Mean	
				Spacing 20 x 50 cm					
TVx 1836-19E	5649	711	176	2178	-	978	1216	1097	20
VITA-1	3171	346	116	1211	-	443	837	640	47
VITA-5	5630	1038	250	2306	-	319	1356	838	76
TVx 33-1G	5035	612	270	1972	-	1069	1859	1464	42
				Spacing 20 x 100 cm					
TVx 1836-19E	5630	1057	404	2363	-	890	1231	1060	28
VITA-1	4727	596	211	1844	-	487	958	722	49
VITA-5	5226	1134	845	2402	-	449	1307	878	66
TVx 33-1G	6053	1057	307	2472	-	1163	2499	1831	54

	LSD (0.05)	
	Weed weight	Seed yield
Weeding	568**	302**
Spacing	188**	134
Cultivar	263**	190**
Cultivar x weeding	455**	235**

*W0 = no weeding, W1 = one weeding at 15 DAP, and W2 = two weedings at 15 and 30 DAP.

**Percent yield losses were calculated from the differences in yield between W1 and W2.

Table 2. Effect of weeding method on weed weight, and yield and dry matter of cowpea, 1977.

Weeding method	Seed yield (kg/ha)	Weed weight (kg/ha)	Total dry matter (kg/ha)
Weed-free	1309 (100%)	6	2540
One weeding at 15 DAP	1276 (97%)	46	2454
Weeding between rows	1065 (81%)	159	2135
Weeding within rows	773 (59%)	479	2062
Mowing up to 5 cm.	961 (73%)	330	2208
No weeding	787 (60%)	967	1929
LSD (0.05)	184	109	308

Table 3. Effect of weeding on weed weight, growth and yield of cowpea.

	Seed yield (kg/ha)		Weed wt. (kg/ha)		Leaf area index		Canopy height (cm)	
Cultivar	W0*	W1**	W0	W1	W0	W1	W0	W1
ER-1	660	1225	1471	4	1.17	2.04	50.5	49.3
VITA-1	739	982	990	13	3.25	3.50	61.5	68.0
TVx 33-1G	611	1327	1195	10	1.89	2.81	63.0	72.5
VITA-5	1139	1705	777	0	2.26	3.00	56.0	52.8
LSD (0.05)	368		218		0.40		4.8	

W0* = No weeding

W1** = With two weedings

Table 4. Effect of weeding and spacing on growth, yield and quality of soybean, 1977.

Cultivar	Spacing(cm)	Seed yield (kg/ha)		Weed weight (kg/ha)		LAI		Smooth clean seed (%)		Germination (%)	
		W0*	W1**	W0	W1	W0	W1	W0	W1	W0	W1
Williams	5 x 75	507	1625	3130	8	1.74	3.07	36.0	66.8	45.3	73.5
	5 x 37.5	1230	1617	1000	227	2.85	2.84	55.5	65.3	63.8	66.3
Bossier	5 x 75	851	1808	1400	13	2.90	3.50	51.0	66.0	56.3	65.5
	5 x 37.5	1369	1644	280	13	4.39	3.67	51.0	73.3	67.5	75.5
Jupiter	5 x 75	327	558	810	13	3.11	3.96	33.8	57.5	35.8	60.0
	5 x 37.5	300	476	120	0	4.08	4.15	52.0	60.3	53.0	68.3
LSD (0.05)		166		440		0.71		8.1		9.3	

W0* = No weeding.
W1** = With two weedings.

Table 5. Effect of spacing on weed control in soybean.

Spacing (cm)	Weeding treatment	Seed yield (kg/ha)	% Losses due to weeds
10 x 75	Without	682	54
	With	1481	
20 x 37.5	Without	1575	19
	With	1934	
30 x 25	Without	1445	18
	With	1765	
5 x 75	With	1172	44
	Without	2070	
10 x 37.5	With	1611	27
	Without	2209	
15 x 25	With	1732	11
	Without	1955	
	LSD (0.05)	230	

Table 6. Effect of weeding on seed yield and quality of soybeans, 1977 S.

Cultivar	Weed weight (kg/ha)		Seed yield (kg/ha)		Germination (%)		Smooth clean seed (%)	
	W0*	W1**	W0	W1	W0	W1	W0	W1
Williams	3801	1066	1221	1709	75	69	69	95
Bossier	1546	235	1472	2049	92	91	90	97
Jupiter	2354	463	1416	1949	95	94	94	94
LSD (0.05)	1649		237		3		2	

W0* = No weeding.
W1** = With one weeding at 30 DAP.