RESPONSE OF COWPEA (*VIGNA UNGUICULATA*) TO TILLAGE AND HERBICIDE MANAGEMENT

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ABSTRACT

Cowpea, *Vigna unguiculata* is used both for human food and animal forage. It may become important as a fall grown forage that fits well into multiple cropping systems in the southern USA and other areas of the world with similar climate. The objectives of this study were to: 1) compare above ground plant cowpea yield, and plant N content under three tillage treatments and 2) determine potential injury and the effectiveness of five weed management programs under these tillage regimes. 'Iron Clay' cowpea was planted 24 August on Millhopper sand in 10 inch wide rows with a no-till Tye drill. Conventional tillage and no-till treatments were main plots with five herbicide combinations as split plots, replicated four times. Above ground dry matter production was determined at late bloom stage (60 days after planting) followed by Kjeldahl N analyses. Crop injury ratings and percent control of weeds were also determined at 15 and 45 days after herbicides were sprayed. This study found that best yields could be obtained with the use of glyphosate herbicide alone to provide a range of 1.27 to 1.55 ton dry matter acre^{-1}. No-till + use of broiler manure was the most consistent in providing best yield for all herbicide combinations except when using pendimethalin (Prowl) + flumioxazin (Valor) which resulted in significant cowpea plant injure (caused by the flumioxazin) for this tillage treatment. Nitrogen content (N concentration x dry matter yield acre^{-1}) mirrored dry matter yield. The use of no-till + broiler manure provided the greatest N content in the range of 75 to 79 pounds N acre^{-1} in dry matter of the above ground cowpea plant.

INTRODUCTION

Cowpea, Vigna unguiculata (L.) Walp. is grown in over two-thirds of the developing world, usually as a companion or relay crop with small grains or corn (Zea mays L.). Its major importance is a staple in the diet of many millions of people. Development of new varieties resistant to insects and pests or have shorter life cycles have contributed to increased cultivation of this crop. Cowpea is adapted to warm weather and requires less rainfall than most crops, therefore it is primarily cultivated in the semiarid regions of the lowland tropics and subtropics, where soils are poor and rainfall is limited (Mortimore et al., 1997).

The use of cowpea as fodder is attractive in mixed crop/livestock systems where both grain and fodder can be obtained from the same crop (Tarawali et al., 1997). In addition, there is increasing emphasis on integrating crop livestock production to promote more sustainable agricultural systems. Cowpea can make a very important contribution towards livestock fodder and supply N to the soil (Lat et al., 1978). Its use as a dual-purpose crop, and providing both grain and fodder is attractive where land is becoming increasingly scarce. The use of cowpea as fodder is most advanced in India, where green material is used for grazing, or cut and mixed with dry cereals for stall feeding (Tarawali et al., 1997). According to Relwani et al., (1970) the use of cowpea in combination with cereals and other crops for lactating cows in India can maintain milk yields of > 1.5 gallon cow-1 day-1. Inclusion of green cowpea pods in the fodder is considered important to raise nutritive value. Trials on fodder varieties of cowpea in India gave dry-matter yields of > 1.8 ton acre-1 and protein contents of up to 26% (Relwani et al., 1970). Cutting trials have indicated that harvesting 60 days after planting gave the best dry matter yields of highest quality (Kandaswamy et al., 1976).

Grain cowpea is planted in semiarid and arid zones of West Africa between millet rows 2 to 3 weeks after planting millet, followed by fodder cowpea 3 to 4 weeks later. Following millet harvest, the grain cowpea is harvested and the fodder cowpea is left to grow. Typical yields are 350 to 400 pounds dry cowpea fodder acre-1 (Singh 1993). Under appropriate management cowpea can provide good quality fodder for in situ grazing, silage (in combination with cereals) or hay. The management and cultivars selected will depend on the farming system requirements and the mode of use (Tarawali et al., 1997).

Farming is becoming a more labor-intensive system in many areas, driven by demographic and economic forces. Cowpea will provide a crucial role as it facilitates crop-livestock integration, which is associated with intensification and land conserving investments. In fixing N, cowpea also brings this plant nutrient into the cycle. Its economic function in the system is complementary to that of cereals (Mortimore et al., 1997).

A best management practice, which reduces soil erosion and conserves water, while at the same time increasing land productivity and conserving fuel, is conservation tillage. Any tillage and planting system that covers 30% or more of the soil surface with crop residue after planting is considered conservation tillage (Gallaher and Hawf, 1997). One tillage cycle destroyed the benefits derived from several years of no-tillage (Broome and Triplett, 1997).

Weed control is essential for no-tillage production. It is very important to carry out trials in order to study the response of cowpea to no-tillage and weed control with herbicides. Herbicides for no-tillage must 1) control vegetation present, 2) prevent growth of weeds from seed, 3) not injure the crop or succeeding crops, and 4) be economical (Triplett et al., 1964). Gutiérrez et al., (1999) carried out a no-tillage trial in Venezuela to evaluate different methods of weed control and to compare two cowpea genotypes. Glyphosate (2 lb ai acre-1) gave the best economic profit and provided >90% weed control.

The public demands that dairy and poultry farmers include manure management as a part of their business operations. The utilization of manure must be protective of the environment. Plant food nutrients in the manure can be valuable resources for production of forage crops but it is important for these systems to produce sufficient yields of high quality forages to feed the animals producing the manure (Johnson et al., 1995). A reason to apply chicken manure as an organic matter source to the soil is to improve aeration, water retention, soil structure and drainage and also to feed earthworms and microorganisms that maintain the balance and biological activity in the soil. Nitrogen, in freshly excreted chicken manure, is in the organic form, which is converted to ammonium-N during storage or after application to the soil. Since ammonium is held firmly to the surfaces of soil particles, it does not leach easily but may, under certain conditions, be converted to volatile ammonia gas (Fraser, 1985). The main value of manure is the plant nutrient content and organic matter. Animals use only about 25% of the nutrients contained in feeds, with the remaining 75% of the original content of N, P and K excreted in manure and urine (Fraser, 1985). Broiler manure, like any fertilizer, should be applied to soil only at rates required to meet crop nutrient needs.

The objectives of this study were to: 1) compare above ground plant cowpea yield, and plant N content under three tillage treatments and 2) determine potential injury and the effectiveness of five herbicide weed management programs under these tillage regimes.

MATERIALS AND METHODS

'Iron Clay' cowpea was planted 24 August at the Agronomy Departments Field Teaching Laboratories, University of Florida. Soil at this site is classified as Millhopper sand (sandy siliceous hyperthermic grossarenic paleudult) (Soil Survey Staff, 1984). The field had been planted in the spring with corn and ears were removed near the end of July. Stalks were chopped and spread evenly over the field on 31 July 2000. Soil fertility test was obtained from samples collected on 1 August 2000. Conventional tillage treatments were tilled on 1 August 2000. Plots were sprayed with a uniform rate of 2 quarts (2 lb ai) roundup (Glyphosate) acre-1 five days prior to planting. 'Iron Clay' cowpea was planted with a Tye no-till drill on 31 August in 10 inch wide rows. Lannate (1 pint acre-1) was applied to control leafhoppers and leaf miners three weeks after planting.

A split-plot experimental design with tillage treatments as main effects in a randomized complete block and 4 replications was used. Tillage treatments included: 1.Conventional tillage, 2. No-till directly into chopped cornstalks-residue from previous crop, and 3. No-till directly into chopped cornstalks-residue from previous crop + broiler manure application to provide the equivalent of 120 pounds N acre-1. Conventional tillage plots were harrowed and tilled following chopped cornstalks. Initial tillage was done on 1 August 2000. The assumption was that N from the broiler manure would be 50% as efficient as if using ammonium nitrate as the N source. This assumption would result in fulfilling the Florida Cooperative Extension recommendation of 60 lb N acre-1 for cowpea.

The sub-effects were the herbicide treatments: 1. untreated check; 2. pendimethalin (Prowl)-0.75 lb ai acre-1, pre-emergence treatment (PRE), 3. pendimethalin-0.75 lb ai/acre PRE + flumioxazin (Valor)-0.078 lb ai acre-1 PRE; 3. Pendimethalin-0.75 lb ai acre-1 PRE + flumioxazin (experimental, not registered for use on cowpea); 4. pendimethalin-0.75 lb ai acre-1 PRE + prometryn (experimental, not registered for use on cowpea)-1.25 lb ai acre-1 PRE; and 5. metalachlor (Dual Magnum) at 0.40-lb ai acre-1 PRE + imazethapyr (Pursuit)-0.032 lb ai acre-1 post-emergence (POST).

Based on soil test all plots were fertilized with 80 lb K20 acre-1 using muriate of potash. Irrigation was applied as needed using overhead sprinklers. Black-eye Cowpea Mosaic Virus (BCMV) was identified on a few plants and destroyed (Plant Disease Diagnostic Clinic, University of Florida).

Three rows per plot were harvested at the late bloom stage, 60 days after planting for this variety, to determine above ground plant yield. Sub-samples were taken to obtain dry matter percent by drying at 70 °C in a forced air oven. Dry plant samples were chopped in a hammer mill, ground using a Wiley mill with a 2.0 mm stainless steel screen and stored in air tight plastic bags.

For N analysis a mixture of 0.100 g (100 mg) of dried plant tissue, 3.2 g of salt-catalyst (9:1 K2SO4:CuSO4), 2 Pyrex beads and 10 ml of H2SO4 was vortexed in a 100 ml Pyrex test-tube under a hood. To reduce frothing, 2 ml 30% H2O2 was added in small increments and tubes were digested in an aluminum block digester at 370 °C for 210 minutes (Gallaher et al., 1975). Tubes were capped with small funnels that allowed for evolving gasses to escape while preserving refluxing action. Cool digested solutions were vortexed with approximately 50 ml of deionized water, allowed to cool to room temperature, brought to 75 ml volume, transferred to square Nalgene storage bottles (Pyrex beads were filtered out), sealed, mixed and stored. Nitrogen trapped as (NH4)2SO4 was analyzed on an automatic Technicon Sampler IV (solution sampler) and an Alpkem Corporation proportioning Pump III.

Cowpea injury (%) and weed control of purple nutsedge (Cyperus rotundus) and Florida pusley (Richardia scabra) were evaluated 15 and 45 days after herbicides were sprayed. Pre-emergence treatments were sprayed on 25 August 2000 at 2:30 pm, 95 °F (air temperature), 100 °F (soil temperature) and 60% relative humidity. The POST treatment (Pursuit + non-ionic surfactant, 0.25% v/v) was sprayed on 8 September 2000 at 10:00 am, 85 °F (air temperature), 80 °F (soil temperature) when the second trifoliate leaf appeared in cowpea and purple nutsedge plants were about 3 inches tall.

Data were placed in a Quatro-Pro (1987) spreadsheet for transformations and preparation of Ascii files. Data were analyzed using MSAT (1985). Analysis of variance was calculated to determine statistical significance. Means were compared using Fisher's Protected LSD test at p = 0.05 and p = 0.10.

RESULTS AND DISCUSSION

Plant Yield

Above ground dry plant yield showed an interaction between tillage and herbicides (Table 1). No differences in yield occurred between the conventional tillage and no-till treatments among the weed control treatments. Yield among these treatments ranged from 1.01 to 1.38 ton dry matter acre-1. The no-till + broiler manure treatment was the most consistent in providing the best yield. This was especially true when using pendimethalin + prometryn or metalachlor + imazethapyr. However, yield for these two treatments were no different from the untreated check. Yield was lowest from the use of pendimethalin + flumioxazin in the no-till + broiler manure treatment (Table 1) and was positively related to cowpea crop injury (Table 3). Based on these data, the narrow row planting of cowpea resulted in quick canopy closure for excellent competition against weeds. This study suggests that best yield could be obtained with the use of glyphosate as a pre-plant burn-down treatment to provide a range of 1.27 to 1.55 ton dry matter acre-1.

Table 1. Dry plant yield of 'Iron Clay' cowpea from tillage and herbicide treatments, fall 2000, Gainesville, Florida.

Herbicide Treatment	Tillage			Average
	Conventional	No-till	No-till+BM	
----- lb ai acre^{-1} ------	----------------------------- Dry plant yield, ton acre^{-1} -----------------------------			
Untreated Check	1.27 A b W	1.29 a w	1.55 a w	1.37
Pendimethalin (0.75 PRE)	1.20 A b W	1.38 a w	1.50 a w	1.36
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	1.37 A W	1.23 a Wx	1.02 b x	1.21
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	1.10 A b X	1.30 a b Wx	1.54 a w	1.31
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	1.07 b X	1.01 b x	1.58 a w	1.22
Average	1.20	1.24	1.44	

Tillage=NS; Herbicides=NS; Interaction=*; CV Herbicides=17.7%
Comparison of tillage means within a herbicide treatment: LSD@0.05 p=0.40; @0.10 p=0.33
Comparison of herbicide means within a tillage treatment: LSD@0.05 p=0.29; @0.10 p=0.24
BM=Broiler Manure; ai=active ingredient in lb acre^{-1}; PRE=pre emergence, POST=post emergence

PLANT N CONTENT (YIELD)

Nitrogen content (N concentration x dry matter yield acre-1) mirrored dry matter yield. Therefore, there was a significant interaction between tillage and herbicide treatments (Table 2). The low yield from use of pendimethalin + flumioxazin for the no-till + broiler manure (Table 1) resulted in the lowest N content. The use of no-till + broiler manure provided the greatest N content in the range of 75 to 79 pounds N acre-1. As was the case for dry matter production (Table 1) the use of glyphosate as a pre-plant burn-down treatment could provide the highest N content (Table 2).

Table 2. Nitrogen content for cowpea from tillage and herbicide treatments, Gainesville, Florida, Fall 2000.

Herbicide Treatment	Tillage: Conventional			Tillage: No-till			Tillage: No-till+BM			Average
----- lb ai acre^{-1} ------	----------------------------------- Plant N, lbs acre^{-1} ----------------------------------- ---									
Untreated Check	65.5	a	W	66.6	A	w	75.7	a	W	69.2
Pendimethalin (0.75 PRE)	60.8	a	W	67.8	A	w	76.3	a	W	68.3
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	65.7	a	W	66.0	A	w	49.0	b	X	60.3
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	57.1	a	X	63.6	A	X	79.4	a	W	66.8
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	57.8	a	X	54.4	A	X	74.9	a	W	62.4
Average	61.4			63.7			71.0			

Tillage=NS; Herbicides=NS; Interaction* =NS; CV herbicides = 16.6%
Mean separation for tillage within a herbicide: LSD @ 0.05 p = 16.1
Mean separation for herbicides within a tillage: LSD @ 0.05 p = 15.6
BM=Broiler Manure; ai=active ingredient in lb acre^{-1}; PRE=pre emergence, POST=post emergence

COWPEA INJURY (%) BY HERBICIDE TREATMENTS

Cowpea injury was not significant among tillage treatments (Table 3). However, injury was observed for three of the five herbicide treatments at the first sampling date. Pendimethalin + flumioxazin and metalachlor + imazethapyr both showed slight early season crop injury but symptoms had diminished by mid-season. Pendimethalin alone did not cause significant injury, therefore the treatment of pendimethalin + flumioxazin can be attributed to flumioxazin.

Table 3. Percent crop injury in a crop of Iron Clay cowpea from tillage and herbicide treatments, fall 2000, Gainesville, Florida.

Herbicide Treatment	Tillage: Conventional	No-till	No-till+BM		Average
----- lb ai acre^{-1} ------	------------------------------ Cowpea injury, % (09/18/00)--------------------------				
Untreated Check	0.0	0.0	0.0		0.0 c
Pendimethalin (0.75 PRE)	0.0	0.0	0.0		0.0 c
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	27.5	21.3	26.3		25.0 a
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	12.5	3.8	3.8		6.7 b
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	16.3	11.3	5.0		10.8 b
Average	11.3	7.3	7.0	NS	@ 0.05

Tillage =NS; Herbicides = **; Interaction = NS; CV Herbicides = 90.0%
Comparison of herbicide means: LSD @ 0.05 p = 6.3; @0.10 p= 5.3

Herbicide Treatment	Conventional	No-till	No-till+BM		Average
	------------------------------- Cowpea injury, % (10/18/00)--------------------------				
Untreated Check	6.3	1.3	7.5		5.0 b
Pendimethalin (0.75 PRE)	6.3	2.5	22.5		10.4 b
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	13.8	11.3	50.0		25.0 a
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	11.3	0.0	0.0		3.8 b
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	5.0	1.3	0.0		2.1 b
Average	8.5	3.3	16.0	NS	@ 0.05

Tillage=NS; Herbicides=**; Interaction = +; CV Herbicides = 156.8%
Comparison of herbicide means: LSD @ 0.05 p=8.5; @0.10 p =6.9
BM=Broiler Manure; ai=active ingredient in lb acre^{-1}; PRE=pre emergence, POST=post emergence

PURPLE NUTSEDGE (CYPERUS ROTUNDUS) CONTROL (%)

Purple nutsedge was not affected by tillage (Table 4). Metalachlor + imazethapyr provided best early season control at 80%. By the second rating date even the control plots showed 55% control of purple nutsedge, which illustrates the importance of crop canopy shading. All other treatments were essentially equal and provided excellent purple nutsedge control by the time of the second rating time (90%).

Table 4. Control of purple nutsedge in a crop of Iron Clay cowpea from tillage and herbicide treatments, fall 2000, Gainesville, Florida.

Herbicide Treatment	Tillage: Conventional	Tillage: No-till	Tillage: No-till+BM	Average	
----- lb ai acre^{-1} ------	----------------------- Purple Nutsedge control, % (09/18/00) ---------------------				
Untreated Check	47.5	52.5	12.4	37.5	c
Pendimethalin (0.75 PRE)	62.5	60.0	29.9	50.8	b
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	83.8	60.0	40.1	61.3	b
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	50.0	67.5	32.5	50.0	b
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	79.8	80.0	79.0	79.6	A
Average	64.5 W	64.0 W	39.0 X @ 0.05		@ 0.05
Tillage=**; Herbicides=**; Interaction=NS; CV herbicides=31.8% Comparison of tillage means: LSD @ 0.05 p = 9.1; @0.10 p = 8.7 Comparison of herbicide means: LSD @ 0.05 p = 14.7; @ 0.10 p = 12.2					
	------------------------ Purple Nutsedge control, % (10/18/00) --------------------				
Untreated Check	47.5	62.5	55.0	55.0	c
Pendimethalin (0.75 PRE)	90.0	87.5	91.3	89.6	b
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	91.3	87.5	91.2	90.0	b
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	91.3	90.0	91.1	90.8	A
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	88.8	90.0	91.2	90.0	b
Average	81.8	83.5	84.0 NS		@ 0.05

Tillage = NS; Herbicides =**; Interaction =NS; CV herbicides=9.48%
Comparison of herbicide means: LSD @ 0.05 p = 64; @ 0.10 p = 0.7
BM=Broiler Manure; ai=active ingredient in lb acre^{-1}; PRE=pre emergence, POST=post emergence

FLORIDA PUSLEY (RICHARDIA SCABRA) CONTROL (%)

Florida pusley was not affected by tillage (Table 5). All herbicide treatments provided 66 to 90% control. Chemical weed control was rather effective in control during the early cowpea growth period compared to the untreated control. However, by the time of the second weed rating most herbicide treatments were no better in their control of Florida pusley then the control treatment. Pendimethalin + flumioxazin was the most consistent in control (Table 5), but this treatment caused the greatest crop injury (Table 3) and the lowest dry matter yield (Table 1) and N content (Table 2).

Table 5. Control of Florida pusley in a crop of Iron Clay cowpea from tillage and herbicide treatments, fall 2000, Gainesville, Florida.

Herbicide Treatment	Tillage: Conventional	Tillage: No-till	Tillage: No-till+BM		Average	
----- lb ai acre^{-1} ------	------------------------ Florida pusley control, % (09/18/00) -----------------------					
Untreated Check	0.0	0.0	0.0		0.0	c
Pendimethalin (0.75 PRE)	70.0	66.3	88.8		75.0	b
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	88.8	90.0	91.3		90.0	A
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	88.8	91.3	91.3		90.4	A
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	72.5	91.3	90.0		84.6	A b
Average	64.0	67.8	72.3	NS		@ 0.05

Tillage = NS; Herbicides =**; Interaction = NS; CV herbicides = 23.7%
Comparison of herbicide means: LSD @ 0.05 p = 13.4; @ 0.10 p = 11.1

Herbicide Treatment	Conventional	No-till	No-till+BM		Average	
	------------------------ Florida pusley Control, % (10/18/00) ----------------------					
Untreated Check	6.3	1.3	7.5		5.0	B
Pendimethalin (0.75 PRE)	6.3	2.5	22.4		10.4	AB
Pendimethalin (0.75 PRE) +flumioxazin (0.078 PRE)	13.8	11.3	26.3		17.1	A
Pendimethalin (0.75 PRE) + prometryn (1.25 PRE)	11.3	0.0	3.8		5.0	B
Metalachlor (0.40 PRE) + imazethapyr (0.032 POST)	5.0	1.3	5.0		3.8	b
Average	8.5	3.3	13.0	NS		@ .05

Tillage = NS; Herbicides =**; Interaction =NS; CV Herbicides = 156.8 %
Comparison of herbicide means: LSD @ 0.05 p = 8.5; @ 0.10 p = 6.9
BM=Broiler Manure; ai=active ingredient in lb acre^{-1}; PRE=pre emergence, POST=post emergence

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LITERATURE CITED

Broome, M.L., and G.B. Triplett. 1997. Weed control for corn planted into Sod. . P 245-247. In R.N. Gallaher and R. McSorley (eds.). Proceedings 20th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Special Series SS-AGR-60. University of Florida Cooperative Extension Service, Gainesville, Florida.

Fraser, H. 1985. Manure characteristics. Resources management branch. Ministry of Agriculture, Food and rural Affairs. In Ontario Web site. Government of Ontario, Canada. 5 pp.

Gallaher, R.N., C.O. Weldon, and J.C. Futral. 1975. An Aluminum block digester for plant and soil analysis. Soil Sci. Soc. Amer. Proc. 39(4):803-806.

Gallaher, R. N., and L. Hawf. 1997. Roles of conservation tillage in production of a wholesome food Supply. P 23-27. In R.N. Gallaher and R. McSorley (eds.). Proceedings 20th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Special Series SS-AGR-60. University of Florida Cooperative Extension Service, Gainesville, Florida.

Gutiérrez, W. C. Medrano, A. Gómez, E. Urrutia, M. Urdaneta, E. Esparza, J. Báez, Y. Villalobos, and B. Medina. 1999. Rev. Fac. Agron. (LUZ). 16:597-609.

Johnson, J.C., Jr., G.L. Newton, J.G. Davis, and P.R. Utley. 1995. Forage production from two minimum-till cropping systems utilizing liquid dairy manure. Animal & Dairy Science. CAES/UGA. Annual Report. P 199-202.

Lat, R.B., D. Rajat, and D.J. Minson. 1978. Legume contribution to the fertilizer economy in legume-cereal rotations. Indian Journal of Agricultural Science 48(7):419-424.

Mortimore, M.J., B.B. Singh, F. Harris, and S.F. Blade. 1997. Cowpea in traditional cropping systems. In advances in cowpea research. Copublication of International Institute of tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Chapter 9. Sayce Publishing. Devon, UK. pp. 99-113.

MSTAT 4.0. 1985. Users Guide to MSAT, Version 4.0 Michigan State University, Lansing, U.S.A.

Kandaswamy, P., P. Muthuswamy, and K.K. Krishnamoorthy. 1976. Effect of stage of cutting on the crude protein, phosphorus content and yield of cowpea (Vigna sinensis L.) The Madras Agricultural Journal 63(3):178-180.

QUATTRO PRO 4.0. 1987. Manual for QUATTRO PRO 4.0, Getting Started. Borland International, Inc., 1800 Green Hills Road, P.O. Box 660001, Scotts Valley, CA 95067-0001.

Relwani, L.L., C.K. Kurar, and R.K. Bagga. 1970. Varietal trial on cowpea (Vigna sinensis) for fodder production. Indian Journal of Agriculture 15(2):166-168.

Singh, B.B. 1993. Cowpea breeding: Archival report (1988-1992). Crop Improvement Division, IITA, Ibadan, Nigeria.

Soil Survey Staff. 1984. Official series description of the Millhopper series. United States Government Printing Office, Wash. D.C.

Tarawali S.A., B.B. Singh, M. Peters, and S.F. Blade. 1997. Cowpea haulms fodder. In Advances in Cowpea Research. Copublication of International Institute of Tropical

Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Chapter 27. Sayce Publishing. Devon, UK. P 313-325.