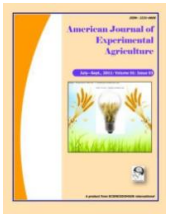

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Evaluation of Tillage Practices on Weed Control and Yield of Groundnut (*Arachis hypogaea* L.) in Sudan Savanna Agro-ecology of Nigeria

A. Lado[1*], M. A. Hussaini[1] and S. G. Mohammed[1]

[1]Department of Agronomy, Bayero University, Kano, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Three years field studies were conducted at teaching and research farm of faculty of Agriculture, Bayero University Kano to evaluate the effect of various tillage practices on weed control and yield of groundnut. The study consisted of nine (9) treatments comprising of two (2) zero tilled, three (3) minimum and four (4) conventional tillage practices arranged in randomized complete block design with three (3) replications. Identification of weeds was made to species level and data were collected on weed count, cover score and weed dry weight. At maturity, groundnut stand and kernel yield were assessed. Data were analyzed using SAS (version 9.3). The result showed a higher weed infestation in T1, T2, T3, T4 and T6 (control) than in T9, T8 and T7 tillage practices from all the three years of study. Perennial weeds species were more frequent in T1 and T2 tilled plots than in T9 and T8 tilled plots. T9 had the least cover score while T6 (control) had the highest weed cover score in all the trials. In all the trials, T1 consistently recorded the highest weed dry matter while T9 recorded the lowest. The highest stands of 35333 ha^{-1} and 37852 ha^{-1} were observed at T9 in 2008 and 2010 trials respectively while control (T6) was among the least. The highest and lowest stands of 41556 and 17778 ha^{-1} were observed at T8 and T5 respectively in 2009 trial. Generally T9 had the highest kernel yield of 1067.7 kg ha^{-1} in 2008 and 1151 kg ha^{-1} in 2010 season. Tillage

**Corresponding author: E-mail: abdulladodoka@yahoo.com;*

practices modified weed floral composition of the study area. T9 and T8 reduced the level of weed occurrences and resulted in better weed control with higher kernel yield than T1, T2, T3, T4, and T6 tillage practices. T8 and T9 tillage practices are recommended for weed control in the study area.

Keywords: Tillage; weed control; groundnut; yield; Sudan savanna.

1. INTRODUCTION

Groundnut (*Arachis hypogaea*) is an important tropical legume and oil crop produced for both domestic and industrial purposes. It used to be one of the most important export crops in Nigeria. It is the sixth most important oil seed crop in the world. It contains 48-50% oil and 26-28% protein, and is rich on dietary fiber, mineral and vitamins [1]. Tillage and weed control are among the most important practices in groundnut production [2,3]. Weed control and tillage practices in crop production are inseparable [4]. When the land is properly tilled, weeds are effectively controlled and this leads to improved crop yield. Soil tillage, which dated back to the beginning of agriculture, is aimed at optimizing soil condition for seed germination, seedling emergence and growth; as well as weed control [3]. Weed shifts are known to occur in continuously cultivated land in response to tillage practices, cropping systems, weed control and other changes in the habitat [2].

Agriculture still relies heavily on mechanical forms of soil disturbances from plowing, harrowing and on use of herbicides for weed control both prior and after planting [2]. These tools reduce weed density and result in favorable yield response. Soil tillage was reported to have determined the absolute and relative abundance of weeds with different traits in a given cropping system [5]. Tillage practices control weeds by breaking, cutting or tearing them from the soil thus exposing the vegetative parts to desiccation and smothering them with soils. Tillage assists greatly in breaking seed dormancy and stimulating seed germination through mechanical scarification [2]. In soils with uniform seed density, cultivation generally stimulates weed seedling emergence causing a faster decline of the soil seed reserves compared to treatment without cultivation. Where weeds are permitted to re-seed, population of annual grasses increased faster in zero-tillage than in conventional tillage systems [6]. Thus, tillage practices strongly influence number and diversity of seeds in soil weed seed bank, depending predominantly on period of induced seed dormancy [2]. Conventional tillage operations primarily invert the soil burying viable weed seeds in topsoil thereby lowering their germination [2].

The production of Groundnut in the study area involves insufficient tillage which leads to high weed infestation. Yield looses in groundnut due to weed infestation can be as high as 77% [6]. Apart from competition for moisture, nutrient and sunlight, weeds may inhibit pegging in groundnut and interfere with crop harvest. Weed competition in groundnut is critical up to 45 days after sowing and weed free environment during this period may likely give higher yield [6]. Manual hoe weeding and row cultivation after emergence but before pegging are effective in controlling weeds establishment but do not provide complete weed free environment necessary for high yield. Manual hoe cultivation during pegging destroys roots and pegs. Thus, once pegging begins, soil disturbance should be avoided or kept to a minimum so as not to interfere with the developing pods. It is important therefore to determine the best methods of tilling the soils that will effectively control weeds and produce high groundnut yield. Very little was done in the study area on the effect of tillage practices on weed control and yield of groundnut. This study was therefore initiated to investigate the effect of different tillage practices on weed control and yield of groundnut.

2. MATERIALS AND METHODS

The trials were conducted at the Teaching and Research Farm of Faculty of Agriculture Bayero University, Kano in 2008, 2009 and 2010 rainy seasons. Kano (11º58N, 8º25E and 475m above sea level) is located within the Sudan savanna zone of northern Nigeria. It has a monomodal rainfall. The total annual rainfall was 990, 699.06 and 731.1mm in 2008, 2009 and 2010 seasons respectively. The monthly mean temperature range from 14.6ºC in January to 39.5ºC in March 2008; 15.87ºC in January to 41.7ºC in April, 2009; 13.96ºC in January to 46.7ºC in April, 2010. The textural class of the experimental soils is loamy sand. Total Nitrogen and organic carbon were 0.041 and 0.759% with cation exchange

capacity of 7.33 cmol kg^{-1}. The experiment involved nine (9) tillage treatments as shown in Table 1 below:

T1 and T2 represent zero tillage where herbicide was applied as pre-plant application, followed by post-emergence application of Fluazifop. During sowing only small cut necessary to bury the seed into the soil was made. T3, T4 and T5 represent minimum tillage which involved incomplete loosening of soil layer with hoe, plow or harrow. It was followed by pre-planting and post-emergence application of herbicide. T6, T7, T8 and T9 represent conventional tillage where the soil was loosened and turned with hoe, plow, harrow and ridger. It was followed by supplementary hoe weeding. The treatments were laid out in randomized complete block design replicated three times. The gross and net plots sizes were 22.5 m^2 and 15 m^2, respectively. The gross plots were demarcated and pegged with iron rods for easy identification in subsequent years. The same site for each treatment was maintained for the whole experimental period. Pre-plant herbicide application was achieved by spraying plots with paraquat at 0.8 kg a.i.ha^{-1} one week before sowing; pre-emergence application was done with pendimethalin at 1.0 kg a.i. ha^{-1} immediately after sowing and post-emergence application with fluazifop at 0.4 kg a. i ha^{-1} at 4 weeks after sowing (WAS).

An extra early maturing groundnut variety (SAMNUT 23) was obtained from Institute for Agricultural Research, Ahmadu Bello University Samaru, Zaria. Two seeds were sown 2cm deep at inter-row and intra-row spacing of 0.75 m and 0.25 m, respectively and thinned to 1 plant per hole at 2 WAS. Fertilizer was applied at 2 WAS using a mixture of NPK (15-15-15%) and single super phosphate (18% P_2O_5) to supply 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1}.

Weed sample was collected from 1M^2 quadrant. Weeds within the quadrant were identified, counted and recorded. Samples within the quadrant were separated by species and the level of infestation determined and cut from the ground level using sickle and oven dried at 75ºC to constant weight for determination of dry weight. Weed cover score was recorded at crop's (groundnut) physiological maturity by visual observation on scale of 1-10; where 1 represented uncovered plots while 10 represented plots completely covered by weeds. Relative weed frequency was estimated using the equation of [7]:

Relative weed frequency = (Frequency of individual weed species/Total frequency of all weed species) x 100

Stands count were recorded by counting the number of groundnut stands at physiological maturity from each net plot area and extrapolated to per hectare basis. Kernel yield was obtained by threshing and winnowing pods; and weighing the kernels obtained from the net plot. The values were extrapolated to kg per hectare. Data generated were subjected to statistical analysis of variance using SAS package (version 9.3). Where treatment means were significant, they were separated using Duncan's Multiple Range Test at 5% level of probability. Correlation analysis was carried out among the groundnut and weed attributes as suggested by [8].

Table 1. Experimental treatments

Treatment number	Treatment description
T1	Paraquat at 0.8 kg a. i.ha^{-1} followed by Fluazifop at 0.4 kg a.i. ha^{-1}
T2	Paraquat at 0.8 kg a. i. ha^{-1} followed by Pendimethalin at 1.0 kg a. i. ha^{-1} followed by Fluazifop at 0.4 kg a.i. ha^{-1}
T3	Hoe tilling followed by Paraquat at 0.8 kg a. i. ha^{-1} followed by Fluazifop at 0.4 kg a. i. ha^{-1}
T 4	Ploughing followed by Paraquat at 0.8 kg a.i. ha^{-1} followed by Fluazifop at 0.4 kg a. i ha^{-1}
T5	Harrowing followed by Paraquat at 0.8 kg a. i ha^{-1} followed by Fluazifop at 0.4 kg a. i. ha^{-1}
T 6	Animal Traction followed by supplementary hoe weeding (Control)
T 7	Manual Cultivation followed by supplementary hoe weeding
T8	Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha^{-1} followed supplementary hoe weeding
T 9	Ploughing followed Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha^{-1} followed by Supplementary hoe weeding

3. RESULTS

A total of 35 weed species belonging to 29 genera and 22 families were identified in the first year (Table 2). Result shows that, T8, T2 and T4 had the highest relative frequency of 12.4% each followed by T7 and the control (T6) while T9 had the least. From the second year trial, a total of 32 weed species belonging to 26 genera and 19 families were identified (Table 3). Result shows that, T2 had the highest (16.8%) relative frequency followed by T1 (15%) and the control (T6) while T9 had the least (6.4%). A total of 20 weed species belonging to 17 genera and 10 families were identified from the third year trial (Table 4). Result shows that, T1, T2, T3, T4 and T6 (control) had the highest relative frequency of 12.3% each followed by T7 (11.1%), T5 and T8 (9.8% each) while T9 had only 7.4%. Perennial weed species comprising of both grasses, sedges and broadleaf were the most predominant species associated with most of the treatments in all the years. The frequency of occurrences and level of infestations of individual species were generally higher in zero tillage (T1 and T2), T3, T4, and T6 (control) than in T8 and T9 treatments in all the years (Tables 2-4).

Table 5 shows the effect of tillage practices on number of weeds per m^2, weed cover scores and weed dry weight during the experimental period. It was observed that T9 had the lowest number of weeds than other tillage practices in all the trials. The results showed that T9 had the least cover score while T6 (control) had the highest weed cover score in all the trials. Influence of tillage practices on weed dry weight is presented in Table 6. The results revealed a significant effect ($P \leq 0.05$) of tillage practices on weed dry weight. In all the trials, T1 consistently recorded the highest weed dry matter while T9 recorded the lowest. Significant ($P \leq 0.05$) treatment effects were also observed on number of plant stands at harvest and kernel yield (Table 6). The highest stands of 35333 ha^{-1} and 37852 ha^{-1} were observed at T9 in 2008 and 2010 trials respectively while control had the least. The highest and lowest stands of 41556 and 17778 ha^{-1} were observed at T8 and T5 respectively in 2009 trial. Generally, T9 had the highest kernel yield of 1067.7 kg ha^{-1} in 2008, 1188.3 kg ha^{-1} in 2009 and 1151 kg ha^{-1} in 2010 season. Yield of T6 (control), T1, T2, T3, T4 and T5 were lower than T8 and T9 in all the trials. The correlation analysis revealed that kernel yield was significantly and positively correlated with number of plant stands ha^{-1} but negatively correlated with weed density, cover score and dry weight (Table 7).

4. DISCUSSION

Three (3) years of c**o**nsistent tillage practices on the same piece of land led to modification of weed floral composition. Similar observations were reported by [2] and [9]. General decrease in number and frequency of weed occurrence were observed in all the treatments across the years. The decrease was more pronounced among conventional than minimum or zero tillage. This is because conventional tillage resulted in frequent cutting of weed seedlings and burial of weed seeds deep into the soil layer. These destroyed the established weeds and prevented viable seeds from geminating. Destruction of established weeds also helped in reduction of seeds build up in the seed bank. Perennial weeds were observed to be more persistent than the other species but their level of infestation were generally lower in conventional (T9, T8 and T7) than in minimum tillage (T4 and T5). Frequent cultivation in T9, T8 and T7 might have depleted the food reserve of perennating organs of these species of weed eventually causing starvation and death of the plant as reported by [10]. It was observed that minimum tillage stimulated the growth of perennial species. [5] reported that in shallow tilled conditions, perennial weeds respond to breakage by producing increased number of shoots and consequently resulted in increased biomass and productivity. Similarly, [11] reported high occurrences of perennial weeds in conventional than zero tilled plots where glyphosate was used. Broadleaf species were more in zero and minimum tillage treatments indicating that the post emergence application of fluazifop was ineffective against these species. The level of infestation and the total relative frequency of T9 were generally lower than other conventional treatments indicating that pre-emergence application of pendimethalin and supplementary hoe weeding was effective in controlling germinating weeds.

Table 2. Influence of tillage practices on weed species compositions and their level of infestation (%) of groundnut field in 2008 Season

	Family	Growth habit	Zero tillage			Minimum tillage			Conventional tillage		
Weed species			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Acanthospermum hispidium	*Asteraceae*	ABL	-	-	13	13	-	-	-	13	-
Alysicarpus vaginalis	*Fabaceae*	PBL	-	-	-	-	-	13	-	-	-
Aneilema beninience	*Commelinaceae*	ABL	-	13	-	13	13	13	13	-	13
Cassia mimosoides	*Caesalpiniaceae*	ABL	13	38	-	13	13	13	13		-
Cassia obtusiforlia	*Caesalpiniaceae*	ABL	63	38	13	13	-	13	13	13	-
Chamaecristus absus	*Caesalpiniaceae*	ABL	-	13	13	13	38	13	13	-	-
Chonchorus oliteruis	*Tliaceae*	ABL	-	13	13	13	13	13	13	-	-
Chloris pilosa	*Poeceae*	AG	-	-	-	38	-	38	13	13	38
Cleome viscose	*Cleomaceae*	ABL	-	-	13	-	-	-	-	-	-
Commilina species	*Commelinaceae*	AN	-	-	13	13	-	-	-	-	-
Cyperus difformis	*Cyperaceae*	PS	63	38	38	63	63	13	13	13	13
Cyperus rotundus	*Cyperaceae*	PS	38	-	13	38	-	-	-	-	-
Crotelera retusa	*Mimosoidae*	ABL	-	-	13	-	13	-	-	-	-
Cynodon dactylon	*Poaceae*	PG	38	38	38	38	38	13	13	13	13
Dactylocteniumm aegytium	*Poaceae*	AG	-	13	13	-	-	-	-	-	-
Digitaria deblis	*Poaceae*	AG	38	13	13	-	-	-	-	-	13
Euphorbia hirta	*Euphorbiaceae*	ABL	-	-	-	-	13	-	-	-	-
Heteropogon contortus	*Poceae*	PG	-	38	38	-	63	38	13	63	-
Hibiscus subdariffa	*Malvaceae*	ABL	-	-	-	-	13	-	-	-	-
Hyphis lanceolata	*Lamaceae*	ABL	-	-	38	-	-	-	-	-	-
Imperata cylindrica	*Poaceae*	PG	38	38	13	13	-	38	-	-	-
Indigofera hirtusa	*Fabaceae*	ABL	-	-	-	-	13	-	13	13	-
Ipomea acquatica	*Convovulaceae*	PBL	13	13	-	13	13	13	13	13	13
Ipomea asorifolia	*Convovulaceae*	PBL	-	-	-	-	13	-	-	-	-
Ipomea vagans	*Convovulaceae*	ABL	-	-	13	13	-	-	-	-	-
Kyllinga pumilla	*Cyperaceae*	PS	38	-	-	-	-	-	13	-	-
Kyllinga squamulata	*Cyperaceae*	PS	63	13	63	13	13	38	38	13	38
Leucas martinicensis	*Labiatae*	ABL	13	38	38	38	13	38	13	13	13
Melochia cordifolia	*Sphenocaceae*	ABL	13	13	13	38	38	38	-	13	13
Mitracarpus villosus	*Portulacaceae*	ABL	-	13	13	-	-	-	-	-	-
Monechum ciliatum	*Acanthaceae*	ABL	38	38	13	13	38	38	13	38	13

	Family	Growth habit	Zero tillage			Minimum tillage			Conventional tillage		
Oldenlandia herbacia	*Rubiaceae*	ABL	13	13	-	-	-	-	-	-	13
Pennisetum pidicelatum	*Poaceae*	AG	13	-	-	-	13	-	13	38	-
Stirga gesneriodes	*Scrophurariaceae*	ABL	-	-	13	-	-	-	-	-	-
Tridax procumbens	*Astreraceae*	ABL	13	-	-	-	-	-	**	13	-
RF %			9.6	12.4	11.0	12.4	11.0	11.0	11.7	12.4	8.2

T_1= Paraquat at 0.8 kg a. i.ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_2= Paraquat at 0.8 kg a. i. ha-^{1} followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_3 = Hoe tilling followed by Paraquat at 0.8 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_4 = Ploughing followed by Paraquat at 0.8 kg a.i. ha-^{1} followed by Fluazifop at 0.4 kg a. i ha-^{1} T_5 = Harrowing followed by Paraquat at 0.8 kg a. i ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_6= Animal Traction followed by supplementary hoe weeding (SHW) T_7= Manual Cultivation followed by SHW, T_8 = Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by SHW T_9= Ploughing followed by Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha-^{1} followed by SHW ABL= Annual broadleaf; AG= Annual grass; PBL= Perennial broadleaf; PG= Perennial grass; PS= Perennial sedges

Table 3. Influence of tillage practices on weed infestation % of groundnut field in 2009 season

Weed species	Family	Growth habit	Zero tillage		Minimum tillage			Conventional tillage			
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Acanthospermum hispidium	*Asteraceae*	ABL	-	-	-	13	-	-	-	-	-
Alysicarpus vaginalis	*Fabaceae*	PBL	13	13	13	-	-	13	-	13	-
Aneilema beninience	*Commelinaceae*	ABL	-	13	-	13	-	13	-	-	-
Cassia mimosoides	*Caesalpiniaceae*	ABL	13	13	-	13	-	13	-	13	-
Cassia obtusiforlia	*Caesalpiniadeae*	ABL	13	13	-	13	13	-	13	-	13
Chamaecristus absus	*Caesalpiniadeae*		-	13	-	13	-	13	-	-	-
Chonchorus oliteruis	*Tiliaceae*	ABL	13	13	-	13	13	13	13	13	-
Chloris pilosa	*Poeceae*	AG	13	-	13	13	-	-	-	-	-
Cleome viscose	*Cleomaceae*	ABL	13	-	13	-	-	-	-	-	-
Commilina species	*Commelinaceae*	AN	-	-	13	-	-	-	-	-	-
Cyperus difformis	*Cyperaceae*	PS	38	13	13	13	13	13	-	13	13
Cyperus rotundus	*Cyperaceae*	PS	13	13	-	13	-	-	13	13	-
Crotelera retusa	*Mimosoidae*	ABL	13	-	-	-		-	-	-	13
Cynodon dactylon	*Poaceae*	PG	38	38	-	38	38	13	13	13	38
Digitaria deblis	*Poaceae*	AG	13	-	-	-	-	38	-	-	13
Euphorbia hirta	*Euphorbiaceae*	ABL	13	-	-	-	-	13	-	-	-
Heteropogon contortus	*Poceae*	PG	13	13	-	-	13	-	-	13	-
Imperata cylindrica	*Poaceae*	PG	13	13	38	38	13	38	-	13	-

Weed species	Family	Growth habit	Zero tillage		Minimum tillage			Conventional tillage			
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Indigofera hirtusa	*Fabaceae*	ABL	13	13	-	-	13	13	13	-	-
Ipomea acquatica	*Convovulaceae*	PBL	13	13	13	13	13	13	-	-	-
Ipomea asorifolia	*Convovulaceae*	PBL	13	-	-	-	-	13	-	-	-
Ipomea vagans	*Convovulaceae*	ABL	-	13	13	-	-	-	-	-	-
Kyllinga pumilla	*Cyperaceae*	PS	-	13	-	-	-	-	13	13	-
Kyllinga squamulata	*Cyperaceae*	PS	13	38	13	13	13	38	38	13	13
Leucas martinicensis	*Labiatae*	ABL	13	38	38	38	13	38	-	13	-
Melochia cordifolia	*Sphenocaceae*	ABL	13	13	13	13	13	-	13	-	13
Mitracarpus villosus	*Portulacaceae*	ABL	-	-	-	-	-	13	13	-	13
Monechum ciliatum	*Acanthaceae*	ABL	13	13	13	-	13	-	-	-	-
Oldenlandia herbacia	*Rubiaceae*	ABL	-	13	13	-	-	-	-	-	-
Pennisetum pidicelatum	*Poaceae*	AG	-	-	-	-	-	13	13	-	-
Tridax procumbens	*Astreraceae*	ABL	13	13	13	-	-	-	-	-	-
RF%			15	16.8	9.6	11.2	9.6	14	8.0	8.8	6.4

T_1= Paraquat at 0.8 kg a. i.ha^{-1} followed by Fluazifop at 0.4 kg a.i. ha^{-1} T_2= Paraquat at 0.8 kg a. i. ha^{-1} followed by Pendimethalin at 1.0 kg a. i. ha^{-1} followed by Fluazifop at 0.4 kg a.i. ha^{-1} T_3 = Hoe tilling followed by Paraquat at 0.8 kg a. i. ha^{-1} followed by Fluazifop at 0.4 kg a. i. ha^{-1} T_4 = Ploughing followed by Paraquat at 0.8 kg a.i. ha^{-1} followed by Fluazifop at 0.4 kg a. i ha^{-1} T_5 = Harrowing followed by Paraquat at 0.8 kg a. i ha^{-1} followed by Fluazifop at 0.4 kg a. i. ha^{-1} T_6= Animal Traction followed by supplementary hoe weeding (SHW) T_7= Manual Cultivation followed by SHW T_8 = Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha^{-1} followed by SHW; T_9= Ploughing followed by Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha^{-1} followed by SHW ABL= Annual broadleaf; AG= Annual grass; PBL= Perennial broadleaf; PG= Perennial grass; PS= Perennial sedges

Table 4. Influence of tillage practices on weed infestation of groundnut Field in 2010 season

Weed species	Family	Growth	Zero tillage		Minimum tillage			Conventional tillage			
			T1	T2	T3	T4	T5	T6	T7	T8	T9
Alysicarpus vaginalis	*Fabaceae*	PBL	-	-	-	-	-	-	-	38	-
Cassia mimosoides	*Caesalpiniaceae*	ABL	13	13	13	13	-	-	-	-	13
Cassia obtusiforlia	*Caesalpiniaceae*	ABL	-	13	-	13	13	-	-	-	-
Chonchorus oliteruis	*Tiliaceae*	ABL	-	-	-	-	-	-	13	-	-
Cleome viscose	*Cleomaceae*	ABL	-	-	-	-	-	-	13	-	-
Cyperus difformis	*Cyperaceae*	PS	63	38	13	13	38	13	13	38	13
Cyperus rotundus	*Cyperaceae*	PS	13	13	38	38	13	13	13	-	13
Cynodon dactylon	*Poaceae*	PG	38	13	38	38	13	13	13	13	13
Euphorbia hirta	*Euphorbiaceae*	ABL	13	-	-	-	-	-	-	-	-

Weed species	Family	Growth	Zero tillage		Minimum tillage			Conventional tillage			
			T1	T2	T3	T4	T5	T6	T7	T8	T9
Heteropogon contortus	*Poceae*	PG	38	38	13	-	13	-	-	-	-
Imperata cylindrical	*Poaceae*	PG	-	13	38	13	-	13	-	13	-
Ipomea acquatica	*Convovulaceae*	PBL	-	-	-	-	-	-	-	13	-
Kyllinga pumilla	*Cyperaceae*	PS	13	-	13	-	-	-	13	-	-
Kyllinga squamulata	*Cyperaceae*	PS	38	13	38	38	-	13	13		-
Leucas martinicensis	*Labiatae*	ABL	13	38	13	13	13	13	-	-	-
Mitracarpus villosus	*Portulacaceae*	ABL	-	-	-	-	-	38	13	13	-
Monechum ciliatum	*Acanthaceae*	ABL	13	13	13	13	38	13	-	13	13
Stirga gesnerioides	*Scrophurariaceae*	ABL	-	-	-	13	-	13	13	13	13
Tridax procumbens	*Astreraceae*	ABL	-	-	13	-	-	13	-	-	-
Physalis angulata	*Scrophurariaceae*	ABL	-	-	-	-	13	13	-	-	-
Relative Frequency %			12.3	12.3	12.3	12.3	9.8	12.3	11.1	9.8	7.4

T_1= Paraquat at 0.8 kg a. i.ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1}; T_2= Paraquat at 0.8 kg a. i. ha-^{1} followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_3 = Hoe tilling followed by Paraquat at 0.8 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_4 = Ploughing followed by Paraquat at 0.8 kg a.i. ha-^{1} followed by Fluazifop at 0.4 kg a. i ha-^{1} T_5 = Harrowing followed by Paraquat at 0.8 kg a. i ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_6= Animal Traction followed by supplementary hoe weeding (SHW) T_7= Manual Cultivation followed by SHW T_8 = Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by SHW T_9= Ploughing followed by Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha-^{1} followed by SHW ABL= Annual broadleaf; AG= Annual grass; PBL= Perennial broadleaf; PG= Perennial grass; PS= Perennial sedges

Table 5. Effect of tillage practices on weed attributes in 2008, 2009 and 2010 rainy seasons in groundnut field

Treatments	Weed density M^{-2}			*Weed cover scores			Weed dry weight Kg ha^{-1}		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
T_1	108a	74.6a	70.2a	7.5ab	7.3ab	7.7a	6752a	3443a	4665a
T_2	93ab	67a	52.8a	6.66cd	6.5bc	7.1a	2493bc	1920b	2253bcd
T_3	97a	83a	68.1a	6.3bcd	6.6bc	6.7ab	7073a	1540b	3863ab
T_4	91ab	80.6a	65.0a	6.0cde	5.3dc	5.5bc	2323bc	1556b	1969cde
T_5	107.3a	76.6a	69.5a	6.6bc	7.0abc	6.5ab	4587b	1443b	2627bc
T_6	60.6ab	55.6ab	50.5a	8.3a	8.6a	6.7ab	2165bc	176b	1570dce
T_7	71ab	58.0ab	48.0a	4.7e	4.0ed	4.8c	1567bc	1490b	1321dce
T_8	83.7ab	86.6a	60.5a	5.1ed	5.5bcd	5.6bc	1183bc	1113bc	887de
T_9	20.6b	22.6b	19.3b	2.3f	2.8e	2.1d	493c	393c	462e
SE±	17.69	10.93	12.77	0.36	0.46	0.65	677.1	232.9	697.0

*Means followed by same letter within a column are not significantly different using DMRT at 5%. a.i.= active ingredient, Kg= Kilogram, ha= hectare *Weed cover score: 1 – 10 scale: 1 = uncovered space, 10 = completely covered T_1= Paraquat at 0.8 kg a. i.ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_2= Paraquat at 0.8 kg a. i. ha-^{1} followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_3 = Hoe tilling followed by Paraquat at 0.8 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_4 = Ploughing followed by Paraquat at 0.8 kg a.i. ha-^{1} followed by Fluazifop at 0.4 kg a. i ha-^{1} T_5 = Harrowing followed by Paraquat at 0.8 kg a. i ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_6= Animal Traction followed by supplementary hoe weeding (SHW) T_7= Manual Cultivation followed by SHW T_8 = Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by SHW T_9= Ploughing followed by Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha-^{1} followed by SHW*

Table 6. Effect of tillage practices on groundnut stands and kernel yield in 2008, 2009 and 2010 rainy seasons

Treatments	Number of stands ha^{-1}			Kernel yield kg ha^{-1}		
	2008	2009	2010	2008	2009	2010
T_1	16667b	21556b	20889f	146.8b	190.4b	160.2b
T_2	20667b	20889b	22296ef	151.3b	191.3b	161.7b
T_3	24222b	29778ab	29333b-e	183.3b	170.9b	168.1b
T_4	17778b	20222b	25704d-e	153.3b	163.7b	179.8b
T_5	20000b	17778b	23111def	171.6b	186.6b	181.6b
T_6	22667b	39333a	30667a-d	181.8b	178.7b	1104.7a
T_7	20000b	40889a	31630abc	932.2b	1231.7a	1161.3a
T_8	25333b	41556a	35259ab	1038.8a	1108.6a	1010.3a
T_9	35333a	39778a	37852a	1067.7a	1188.3a	1151.3a
SE±	2205.2	4488.1	3548.0	16.81	23.33	25.83

Means followed by same letter(s) within a column are not significantly different using DMRT at 5% a.i.= active ingredient, Kg= Kilogram, ha= hectare T_1= Paraquat at 0.8 kg a. i.ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_2= Paraquat at 0.8 kg a. i. ha-^{1} followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a.i. ha-^{1} T_3 = Hoe tilling followed by Paraquat at 0.8 kg a. i. ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_4 = Ploughing followed by Paraquat at 0.8 kg a.i. ha-^{1} followed by Fluazifop at 0.4 kg a. i ha-^{1} T_5 = Harrowing followed by Paraquat at 0.8 kg a. i ha-^{1} followed by Fluazifop at 0.4 kg a. i. ha-^{1} T_6= Animal Traction followed by supplementary hoe weeding (SHW) T_7= Manual Cultivation followed by SHW T_8 = Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a. i. ha-^{1} followed by SHW T_9= Ploughing followed by Harrowing followed by Ridging followed by Pendimethalin at 1.0 kg a.i. ha-^{1} followed by SHW

Table 7. Correlation coefficient of kernel groundnut yield and some weed parameters for three years combined

	Kernel yield	No. of stand at harvest	Weed cover score	Weed density	
Kernel yield	-				
No. of Stand at harvest	0.30348*	-			
Weed cover score	-0.55778**	-0.36496*	-		
Weed density	-0.31514*	0.05568ns	0.59834**	-	
Weed dry weight	-0.47454**	-0.21196ns	0.51042**	0.3236*	-

*=significant at 5%, ** = significant at 1% level of probability*

T1 and T9 had consistently produced the highest and lowest number of weeds per m^2, highest and lowest weed cover score, as well as highest and lowest weed dry weight, respectively. These may likely be due to reduction in number of weeds per m^2, weed cover score and biomass in T9 as well as fragmentation of weeds and their exposure to desiccation due plowing and harrowing. Similar observations were reported by [3]. Highest weed cover score and weed biomass of zero tilled plots (T1), suggested higher weed competition. This was confirmed by high level of weed infestation on these plots and frequency of weed occurrences as indicated in Tables 2 - 5. Higher number of stands and kernel yield were recorded in conventionally tilled plots while the lowest was observed in zero and minimum tilled plots. Highest number of stands in T9 could be attributed to good soil pulverization, which provided an ideal environment for germination and seedling emergence. High infestation by rodents that picked the sown seeds in zero tilled plots could explain the reason for low number of stands recorded in these treatments. Reduced competition from weed for the available environmental resources due to effective weed control in the T9 treatment might have favored higher kernel yield. Similar observations were reported by [3] and [12]. Lower kernel yield was recorded in zero tilled plots probably because of higher weed pressure as indicated by higher weed density, weed cover score and weed dry weight. Similar observations were reported by [6].

Significant but negative correlations were observed between kernel yield and most of weed characters studied. These indicated that as weed characters increased the grain yield decreased due to competition between the crop and the weeds for environmental resources. Similar observation was reported by [13] in cowpea. Although T9 was more effective in controlling weeds as evident by less weed dry weight; less weed cover score; and less weed density; it was however the most uneconomical. A simple cost analysis revealed that about \$29.697 ha^{-1} will be required for T1, as compared to \$41.82 ha^{-1} for T2; \$66.06 ha^{-1} for T3; \$78.18 ha^{-1} for T4; \$66.06 ha^{-1} for T5; \$169.697 ha^{-1} for T6; \$175.757 ha^{-1} for T7; \$193.93 ha^{-1} for T8; and \$264.24 ha^{-1} for T9. The implements required for plowing, harrowing and ridging were also costly and not always available in the study area. Human labour required for supplementary hoe weeding was also very expensive and often not always available at the time of critical need. High cost of manual labour for weeding has been reported by [13] in rainfed and irrigated cowpea.

5. CONCLUSION

From the results obtained, it can be concluded that tillage practices had significant relationship with weed occurrence, as well as kernel yield of groundnut. Although conventional tillage (T8 and T9) had persistently produced better and more desirable effect on yield and weed control, yet some salient issues may be raised against it, especially in terms of cost and time needed for its operation. Zero and minimum tillage may still be at par with conventional system, if time and costs of operation were factored into it. Therefore T9 and T8 can be recommended for weed control in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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