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Yield Response of Groundnut (Arachis hypogaea) to Weeding Regime and Plant Spacing

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Abstract
Field experiments were conducted at the Plantation Section of the Faculty of Agriculture, KNUST. The experimental design was a 4 x 3 factorial, arranged in a Randomized Complete Block Design (RCBD) with three replications. The treatments comprised four levels of weeding (No-weeding or control (W0), weeding 2-3 weeks after planting (W1), weeding 3-4 weeks after planting (W2) and weed-free (W3) and three levels of plant spacing which included 20 cm x 20 cm, 30 cm x 30 cm and 30 cm x 45 cm. The results showed that total dry matter, pod and grain yields, number of pods per plant, and harvest index showed significant response ($P<0.05$) to weeding in both 2007 and 2008. The highest grain yields of 1034 kg ha^{-1} and 3579 kg ha^{-1} were produced by the weed-free treatment in 2007 and 2008, respectively. Results of the two seasons indicated that total dry matter, pod and grain yields and number of pods per plant were influenced by plant spacing. However, harvest index did not show any significant effect ($P>0.05$) with spacing in both seasons. The closest spacing (20cm x 20cm) recorded the highest total dry matter, pod and grain yields, and harvest index, with the highest grain yields being 969 kg ha^{-1} and 3449 kg ha^{-1} in 2007 and 2008. Farmers should adopt the weed-free and the closest spacing treatments since they produced the highest pod and grain yields in the experiment of the two seasons.
Keywords: Groundnut, yield, spacing, weeding

INTRODUCTION

Groundnut (*Arachis hypogaea*) is a day neutral, leguminous annual herbaceous oil seed crop (Norman *et. al*., 1996). Groundnut is grown on 26.4 million hectares worldwide with a total production of 36.1 million metric tons, and an average productivity of 1.4 metric tons ha^{-1} (FAO, 2004).

Groundnut is an important food crop of the world and also a source of income for farmers.

Groundnut cultivation is influenced by a number of factors such as climatic factors, edaphic (soil factors) and biological factors such as pests and diseases and agronomic factors such as spacing and weed management.

According to Sweet and Minotti (1980), moisture is implicated early during the first three weeks after emergence in weed-crop competition before other growth factors becoming limiting. Akobundu (1987) and Youdeowei (2002) indicated that weeds acted as hosts to pests and harbour many fungal, viral and bacterial diseases. IITA (1997) showed that uncontrolled weeds reduced yields of semi prostrate and erect crops by 68% and 78% respectively. Akobundu (1978) reported that all crops are sensitive to early weed interference and should be cleared within the first two to three weeks after planting.

Proper spacing ensures adequate ventilation, reduces competition among plants for space and nutrients, and reduces transmission of diseases, facilitates weeding and movement in the farm and also reduces over-crowding and, therefore, allows interception of radiation by plant canopies. Kvien and Bergmark (1987) observed that between 64% and 69% of pods failed to reach maturity in early sowings at high density, irrespective of field location.

Generally, correct timing of weeding and proper spacing are imperative in the determination of yield in groundnut cultivation.

Therefore, the objectives of this study were to determine:
(i) the best time at which weeding should be done
(ii) and the yield response of groundnuts to different spacing.

MATERIALS AND METHODS

The experiment was conducted at the Plantation Section of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, in 2007 and 2008. The area falls within latitudes 6’35N -6’40N and longitudes 1’30W-135W and sited within the elevation of 250m- 300m above sea level. The land was previously cultivated to cassava and left fallowed for one year.

The experimental design was a 4x3 factorial arranged in a Randomized Complete Block Design (RCBD) with three replications. There were thus twelve treatments in total. The size of each plot was 2.7m x

4.5m with 1m between plots and 2m between blocks.
Factor A – Weeding regime
W0: No weeding; W1: Weeding 2-3 weeks after planting
W2: Weeding 3-4 weeks after planting
W3: Weed-free (weeding when necessary)
Factor B – Plant spacing
S1: Spacing of 20cm x20cm (250,000 plants/ha)
S2: Spacing of 30cm x30cm (111,111 plants/ha)
S3: Spacing of 30cm x45cm (74,740 plants/ha)
Groundnut seeds were planted with two seeds per hill in the major seasons of 2007 and 2008, respectively. Harvesting was done at physiological maturity.

Data collected

The number of plants per m^2 for each treatment was harvested and the pods were stripped and sun-dried to constant weight and the dry weight measured. The percentage pod formation was computed by expressing the well-filled pods as a percentage of the well-filled pods, unfilled and immature pods combined. The harvest index was calculated by dividing dry seed weight (Economic yield) by the sum of dry pod weight and shoot dry weight (biological yield or total dry matter). Pods collected from sampled plants were counted. The total number of pods was divided by the number of plants harvested per square metre per each treatment to get the mean number of well-filled pods per plant. The total dry matter yield was determined by adding the total shoot dry matter to total dry pod weight.

Data analysis

Analysis of variance was used to analyse all data using the (GENSTAT, 2007) package. The Least significant difference at 5%probability was used to compare treatment means.

RESULTS

Results showed significant effect ($P<0.05$) with weeding and spacing (Table 1). The weed-free treatment (W3) produced the highest pod yield, while the least value was shown in the no-weeding treatment (W0). Similarly, the closest spacing (S1) resulted in the highest pod yield, while the least was recorded by the widest spacing (S3) in 2007 and 2008 (Table 1). The best treatment interaction was recognized in weed-free and closest spacing (W3S1), while the no-weeding and widest spacing (W0S3) had the least in all the two seasons of study.

Total dry matter yield followed similar trend as pod and grain yields in the major seasons of 2007 and 2008, respectively. The highest ($P<0.05$) total dry matter yield (TDMY) was found in the weed-free treatment (W3), while the no-weeding (control) treatment gave the lowest total dry matter yield (TDMY) in the two seasons of study (Table 1). The closest spacing of 20 cm x 20 cm significantly ($P<0.05$) had the highest total dry matter yield (TDMY), while the widest spacing of 45 cm x 30 cm produced the least TDMY in the two seasons. The interaction of the weed-free treatment and the closest spacing (W3S1) recorded the greatest total dry matter yield, while a combination of the no-weeding treatment (control) and the widest spacing (W0S3) registered the lowest value through out the study (Table 1).

Results of percentage pod formation indicated that the no-weeding (control) treatment recorded the lowest percentage pod formation and differed significantly ($P<0.05$) from all other weeding treatments in 2007 (Table 1). The weed-free treatment (W3) of 2007 had the greatest percentage pod formation. The closest and intermediate spacing did not differ significantly ($P>0.05$) from each other, but they were significantly ($P<0.05$) different from the widest spacing in 2007. The widest spacing gave the highest percentage pod formation, while the least percentage pod formation was found in the closest spacing in the major season of 2007 (Table 1). Results showed that the weed-free treatment (W3) and the widest spacing (S3) recorded the highest percentage pod formation, while the no-weeding (control) and the closest spacing (S1) gave the least value in 2008 (Table 1).

Spacing did not have any significant influence ($P>0.05$) on harvest index in the major season of 2007. However, the weed-free treatment (W3) which gave the best harvest index (0.40), varied significantly ($P<0.05$) from the other weeding treatments, while the no-weeding treatment (control) recorded the lowest harvest index (0.21) in the major season of 2007. Harvest index was significantly affected ($P<0.05$) by weeding in 2008 (Table 1). The weeding 2-3 weeks after planting treatment (W1) recorded the highest value. Spacing did not have any significant influence ($P>0.05$) on harvest index in 2008. However, harvest index increased as spacing was narrowed (Table 1). The greatest harvest index was associated with weeding 2-3 weeks after planting treatment and the widest spacing (W1S3). Conversely, the lowest harvest index was noticed in the weed-free and the widest spacing (W3S3).

Table 1: The effect of weeding and spacing on pod yield, total dry matter yield, percentage pod formation and harvest index of groundnut in the major seasons of 2007 and 2008

Treatment	Pod yield (kg/ha)		Total dry matter yield (kg/ha)		% pod formation		Harvest index	
	2007	2008	2007	2008	2007	2008	2007	2008
Weeding								
W0	414.0	376.0	983.0	779.0	16.80	36.60	0.21	0.32
W1	1198.0	3960.0	1934.0	7484.0	40.80	57.30	0.34	0.40
W2	1357.0	4684.0	2576.0	10020.0	39.50	70.10	0.35	0.35
W3	1580.0	5179.0	3054.0	11037.0	41.10	70.20	0.40	0.32
LSD (5%)	143.3	932.6	122.3	1311.7	8.65	9.09	0.05	0.05
Spacing								
S1	1357.0	4637.0	2794.0	9446.0	27.10	53.80	0.34	0.36
S2	1064.0	3374.0	1948.0	6851.0	32.20	57.60	0.33	0.35
S3	991.0	2637.0	1661.0	5693.0	44.40	64.20	0.33	0.33
LSD (5%)	124.1	807.6	105.9	1135.9	7.49	7.87	0.04	0.04
Grand mean	1137.00	3550.00	213.0	7330.0	34.60	58.50	0.33	0.35
CV (%)	12.90	26.90	5.90	18.30	25.60	15.90	14.20	13.90

In the major season of 2007 (Table 2) and 2008, weeding and spacing significantly ($P< 0.05$) influenced number of pods per plant (Figures 1a and 1b). The weed-free treatment (W3) of all the two seasons and the weeding 3-4 weeks after planting treatment (W2) of 2007 produced the highest number of pods per plant, while the no-weeding treatment (W0) gave the least in the two seasons of study. Similarly, the widest spacing (S3) produced the greatest number of pods per plant, while the closest spacing (S1) recorded the least number of pods per plant in 2007 (Table 2) and 2008 (Figures 1a and 1b). The highest treatment interaction effect was observed in the weed-free and widest spacing (W3S3) in the two seasons of study, while the least was obtained by the no-weeding and intermediate spacing (W0S2) in the major season of 2007 (Table 2) and the no-weeding and the closest spacing (W0S1) in 2008 (Figures 1a and 1b).

Results showed that grain yield was significantly ($P<0.05$) affected by weeding and spacing in the major season of 2007 (Table 2) and the major season of 2008 (Figures 2a and 2b). The weed-free treatment (W3) and the closest spacing (S1) recorded the highest grain yield. However, the no-weeding treatment (W0) and the widest spacing (S3) recorded the lowest value. The best treatment interaction was observed in weed-free and closest spacing (W3S1), while the no-weeding and widest spacing (W0S3) had the least.

Table 2: The effect of weeding and spacing on number of pods per plant and grain yield of groundnut in the major season of 2007

Treatment	No. of pods per plant	Grain yield kg/ha
	2007	2007
Weeding		
W0	2.95	236.0
W1	12.75	820.0
W2	16.14	934.0
W3	16.14	1034.0
LSD (5%)	2.84	122.7
Spacing		
S1	5.98	969.0
S2	10.44	651.0
S3	17.28	648.0
LSD (5%)	2.46	106.2
Grand mean	11.23	756.00
CV (%)	25.90	16.60

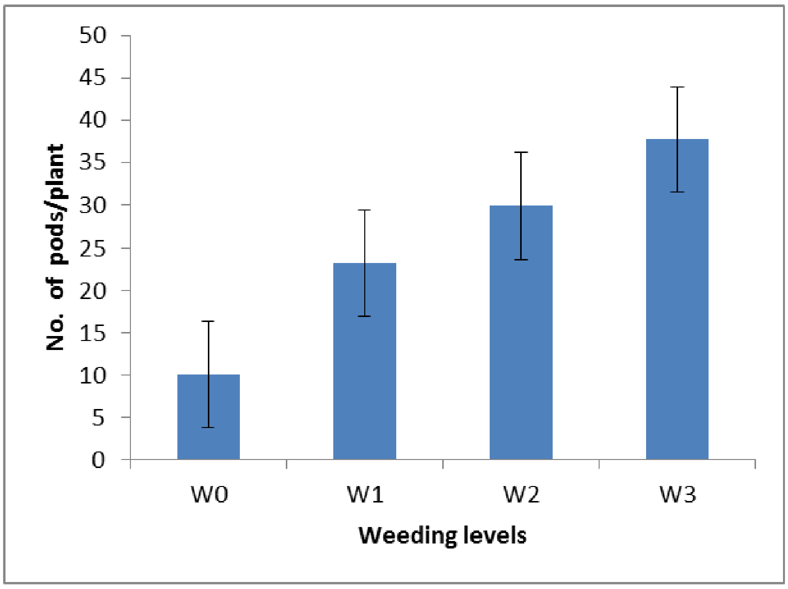

Figure 1a: The effect of weeding on number of pods per plant in the major season of 2008
LSD at 5% was 6.24.

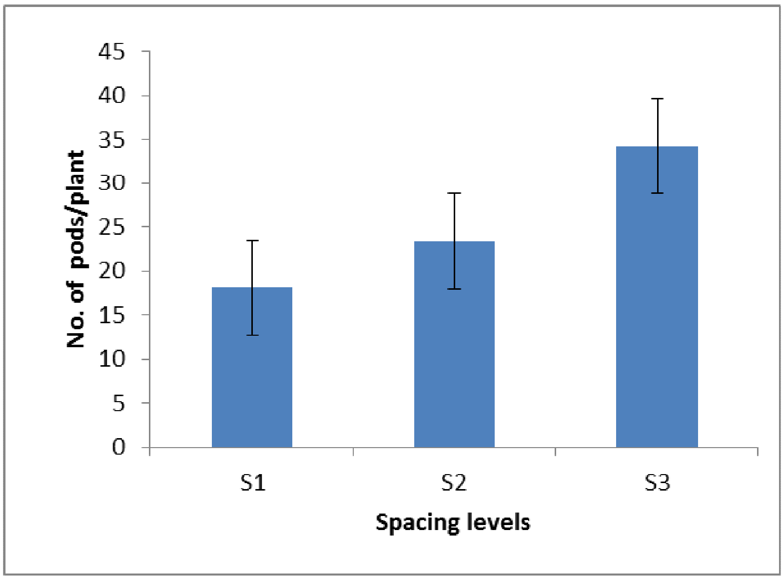

Figure 1b: The effect of spacing on number of pods per plant in the major season of 2008
LSD at 5% was 5.40.

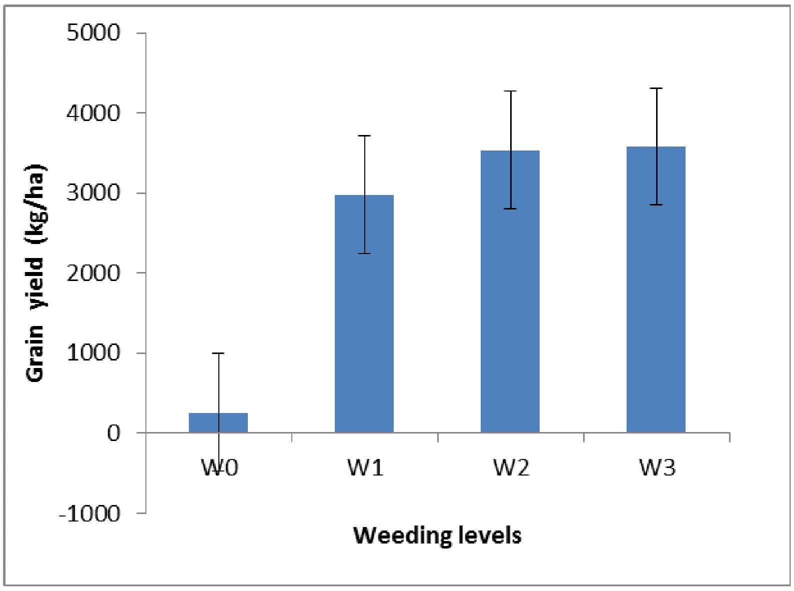

Figure 2a: The effect of weeding on grain yield in the major season of 2008
LSD at 5% was 734.70.

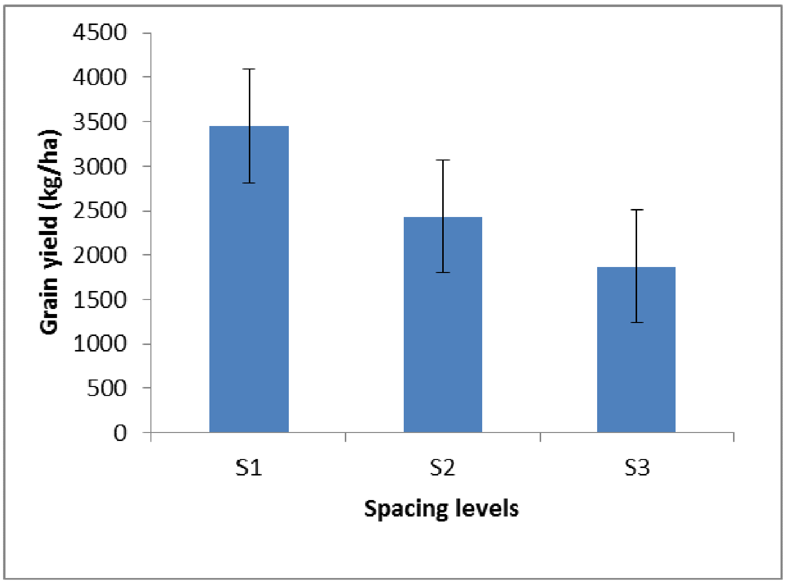

Figure 2b: The effect of spacing on grain yield in the major season of 2008
LSD at 5% was 636.30.

DISCUSSION

The weed-free treatment (W3) recorded the highest pod yields of 1580 kg ha^{-1} and 5179 kgha^{-1} in the major seasons of 2007 and 2008, respectively. Similarly, the highest grain yields of 1034 kg ha^{-1} and 3579 kg ha^{-}1 in the major seasons of 2007 and 2008, respectively were found in the weed-free treatment (Tables 1 and 2 and Figures 2a and 2b). The highest pod and grain yields recorded by the weed-free treatment were probably due to lower competition for available resources. In addition, the production of higher number of pods per plant, higher pod weight, higher shelling percentage, and higher harvest index due to reduced competition for available resources as indicated in the response of peanut to weeding by Duncan *et al*. (1978) could also have contributed to the results. The results agree with work by Donald and Hamblin (1976) who found that increased grain yields in small grains were primarily due to increases in the harvest index.

The no-weeding treatment (control) produced the least pod yield of 414 kg ha^{-1} and 376 kg ha^{-1} in the major seasons of 2007 and 2008, respectively. The least grain yield of 236 kg ha^{-}and 256 kg ha^{-1} was observed in the no-weeding treatment in both 2007 and 2008. The least pod and grain yields for the no-weeding (control) treatment may be due to increased crop-weed competition for soil resources, mutual shading of leaves, premature leaf fall, lower number of branches and pods. The results corroborate with work by Sweet and Minotti (1980) and Youdeowei (2002) who observed that moisture is implicated early in weed-crop competition before other growth factors become limiting and that weeds act as hosts to pests and harbour many fungal, viral and bacterial diseases. The results also agree with the findings of the International Institute of Tropical Agriculture (IITA, 1997) which found that uncontrolled weeds reduced yields of semi prostrate and erect groundnut crops by 68% and 78% respectively. Percentage pod yield reduction for the major seasons of 2007 and 2008 were 73.80% and 92.74%, respectively. These were in accordance with work done by RMRDC (2004) that weeds could reduce groundnut yield by 18-70%. The results were also in conformity with work by IITA (1997) that uncontrolled weeds could reduce yield of some crops by 68-78%.

Results showed that the closest spacing (20cm x 20cm) recorded the highest pod yield of 1357 kg ha^{-1}(2007) and 4637 kg ha^{-1} (2008). For grain yield, the greatest values of 969 kg ha^{-1} and 3449 kg ha^{-1} for 2007 and 2008, respectively were revealed by the closest spacing.

The highest pod and grain yields recorded by the closest spacing could be due to the optimum plant population per unit area, efficient use of resources, higher number of pods per unit area, higher shelling percentage, biological yield and harvest index, less crop-weed competition and a better ground cover leading to higher moisture conservation as observed by Kathirvelan and Kalaiselvan (2007). Shibles *et al*. (1975) and Agasimani *et al*. (1984) reported that narrow row culture called for higher plant densities that ensured faster canopy development to compete successfully against weeds resulting in higher pod and grain yields. Results of higher pod and grain yields probably due to optimum plant population as reported by Ramesh and Sabale (2001) and Hameed-Ansari *et al*. (2007) are in agreement with the present results. In general, as plant population density increases, number of seeds in the larger size grades tends to increase. Work by Kvien and Bergmark (1987) supports this claim. They found that high interplant competition at high densities tended to suppress the development of later reproductive growth and, typically, earlier flowers were more successful at setting seed. Work by Ahmad and Mohammad (2007) showed that pod yield was 16% higher in narrow-row plantings compared with traditional wide-row plantings. Similarly, Duke and Alexander (1964) had earlier reported pod yield among narrow-row peanuts to be 14% higher than wide-row peanut plants.

However, results of the present study (Table 2) showed that as plant population increases, yield components per plant decrease with the number of pods per plant and seed weight per pod being reduced more dramatically than individual pod weight and this is consistent with work of Norman *et al*. (1996).

The widest spacing (30cm x 45cm) gave the least pod yield of 991 kg ha^{-1} and 2637 kg ha^{-1} with the lowest grain yields of 648 kg ha^{-1} and 1872 kg ha^{-1} for 2007 and 2008, respectively. The reduction in pod and grain yields by the widest row spacing might be due to lower plant population per unit area and greater crop-weed competition. This result corroborates with that of Donald (1963) that loss of efficiency as a result of large load of flowers due to lower plant population per unit area and greater crop-weed competition at the widest spacing reflected greater intraplant competition, resulting in fewer seeds per pod and reduced seed size compared to denser stands.

The interaction between weed-free and the closest spacing (20cm x 20cm) recorded the highest pod and grain yields in 2007 with a combination of weeding 3-4 weeks after planting and closest spacing recording the greatest pod and grain yields in 2008. This could be due to the combined effect of adequate growth resources and optimum plant population per unit area. The least pod and grain yields recorded by the interaction of no-weeding (control) and the widest spacing may be due to the combined effect of greater weed-crop competition and lower plant population per unit area.

Again, results showed that the 2008 trial, with the lowest rainfall amount, recorded the highest pod and grain yields (Table 1, and Figure 2b). The mean grain yield in 2008 of 2585 kg/ha as against 756 kg/ha of 2007 could probably be due to better soil-water relations, inherent soil fertility and the residual influence of applied fertilizer in the preceding season which led to the production of better yield components.

Results showed that the number of pods per plant (16.1 and 37.7 for 2007 and 2008, respectively) significantly ($P<0.05$) increased in the weed-free treatment. Higher number of pods per plant recorded by the weed-free plots could be due to low crop-weed competition for available resources and the higher number of branches per plant. The results are supported by the findings of Agasimani *et al*.(1984) that unlimited supply of resources due to weeding increased lateral growth, number of branches and pods per plant. In addition, frequent earthing up could have facilitated more number of gynophores to reach the soil. This agrees with the claim by Sathyamoorthi *et al.* (2007) that earthing up encouraged pegging and podding.

Similarly, the widest spacing which had the highest number of pods per plant in the experiment of the two seasons was probably due to sufficient space between rows which encouraged more vigorous plants, higher number of branches, flowers, pegs per plant, fertility co-efficient, percentage pod formation and lesser interplant competition for resources culminating in more partitioning efficiency. Work by Mozingo and Steele (1989) revealed that the number of pods per plant increased under the widest spacing due to availability of more resources compared to narrow-row peanut plants. These results are in accordance with the present work.

The highest percentage pod formation (Table 1) recorded by weed-free (W3) and weeding 2-3 weeks after planting (W1) in the experiment of the two seasons was probably due to the positive effect of early weed control that led to increased number of branches, number of flowers, number of pegs per plant and fertility co-efficient. The results are supported by the work of Choudhari *et al.* (1985) who observed that the primary branches contributed the majority (about 90%) of pods. The lowest percentage pod formation observed in the no-weeding treatment (W0) could be due to the mining of resources by weeds and their allelopathic effects, premature abscission of leaves and flowers. This was consistent with work by Agasimani *et al*., (1984) who found that the mining of growth resources by weeds and their allelopathic effects could cause flower abortion and reduce percentage pod formation. Oudhia (2003) also found that high weed biomass may cause droughty conditions which could suppress percentage pod formation and consequently the number of pods formed per plant. Chapman *et al*. (1993) stated that drought during pod-filling caused abortion which could cause 45% loss of yield through the death of the youngest pods. The reports of Oudhia (2003) and Chapman *et al*. (1993) collaborate with the results of this study.

The widest spacing recorded the highest percentage pod formation in the experiment of the two seasons (Table 1). The results may be due to higher number of pods per plant, lower interplant competition for resources and more partitioning efficiency of plants. Work of Ramesh and Sabale (2001) supports this claim.

Harvest index is an indicator of how much of the total dry matter accumulated by the plants is partitioned into the economic part (pod). Pod filling is sensitive to moisture stress. Moisture stress and soil fertility factors have been reported to adversely influence dry matter production and partitioning among plant parts in groundnuts (ICRISAT, 1994). Donald and Hamblin (1976) found in 'Dixie Runner' a harvest index of 0.23 and a biological yield of 10.8 Mg (metric ton)/ha. They again, indicated that 'Early Runner' showed a 50% increase in seed yield over Dixie Runner', primarily due to an increased harvest index of 0.36.

The results indicated that harvest index was higher (0.40) in weeding 2-3 weeks after planting treatment for 2008. Weed-free treatment had the highest harvest index (0.40) in 2007. The higher harvest index recorded by the weed-free and weeding 2-3 weeks after planting treatments could be ascribed to reduced competition for available resources, efficient partitioning of assimilates, higher number of pods per plant and grain yields. Results of harvest index obtained in the trials agree with the work of Agasimani *et al*. (1984).

However, weed-free and the no-weeding treatments recorded the lowest harvest index (0.32) in 2008. The excessive vegetative growth in the weed-free treatment could not efficiently translate into economic yield which resulted in a lower harvest index. The lower harvest index recorded by the no-weeding treatment was attributed to reduced yield attributes.

Though spacing did not affect harvest index, the closest spacing recorded the highest value in the experiment of the three seasons. The results could be ascribed to complete canopy closure leading to adequate light interception, photosynthate production, partitioning of assimilates and higher seed yield. The complete canopy closure would smother weed growth which could reduce nutrient and moisture mining by weeds. At the widest spacing, there could be the production of more branches and flowers which could lead to intra-plant competition. The results are in agreement with those of Donald (1963) who found that the loss of efficiency at the widest spacing reflected greater intra-plant competition resulting in fewer seeds per pod and lower harvest index compared to denser stands.

The weed-free treatment gave the highest total dry matter yield of 3054 kg ha^{-1} and 11037 kg ha^{-1} in 2007 and 2008, respectively. The highest total dry matter yield given by the weed-free treatment could presumably be due to lower competition for available resources, low occurrence of pests and diseases and an efficient dry matter partitioning. The closest spacing (20cm x 20cm) recorded the greatest total dry matter of 2794kg ha^{-1} and 9446 kg ha^{-1}in 2007, and 2008, respectively. The highest total dry matter production obtained under the closest spacing (20cm x 20cm) was presumably due to higher plant population, biological yield, harvest index, pod and grain yields. These results agree with the findings of Kathirvelan and Kalaiselvan (2007) who found that total dry matter yield of groundnut generally increased with narrow spacing.

The no-weeding treatment (control) recorded the least dry matter yield of 983 kg ha^{-1} and 779 kg ha^{-1} in 2007 and 2008, respectively probably due to resource mining, mutual shading of leaves and premature senescence (defoliation). The widest spacing had the least total dry matter in the experiment of the two seasons probably due to lesser plant population. The results conform to those of Subrahmaniyan *et al.* (2007) who found that the widest spacing yielded a lower total dry matter output as a result of lesser plant population per unit area. The interaction of weed-free and the closest spacing (W3S1) recorded the highest total dry matter yield throughout the study. The results could be ascribed to the combined effect of reduced competition for resources, higher plant population, biological yield, harvest index, pod and grain yields. The highest total dry matter yield was observed in the major season of 2008.The results may be due to favourable rainfall distribution, adequate temperature, suitable soil-water relationships and efficient dry matter partitioning in 2008 culminating in better vegetative and reproductive growth.

CONCLUSION AND RECOMMENDATIONS

The results showed that weed-free treatment recorded the highest pod, grain and total dry matter yields in the experiment of the two seasons. The number of pods per plant increased in the weed-free treatment in both seasons of the experiment, but had the same value with weeding 3-4 weeks after planting treatment in 2007. The greatest percentage pod formation was recorded by weed-free in the experiment of the two seasons. The greatest harvest index was recorded by the weed-free treatment in 2007, while weeding 2-3 weeks after planting recorded the highest in 2008.

The widest spacing had the highest number of pods and percentage pod formation throughout the study.

The closest spacing (20cm x 20cm) gave the highest pod, grain and total dry matter yields and harvest index throughout the study.

The best treatment interaction was observed in the weed-free and closest spacing (W3S1) for pod and grain yields in 2007. However, in the major season of 2008, the interaction of weeding 3-4 weeks after planting and the closest spacing (W2S1) recorded the highest pod and grain yields.

Total dry matter yield was greatest in the weed-free and closest spacing (W3S1) interaction throughout the study. Similarly, the interaction of weed-free and widest spacing (W3S3) gave the highest number of pods per plant in the experiment of the two seasons.

Recommendation

It is recommended that in further work, treatments should be modified to study varietal responses to treatment application. Treatment modification should include weeding 1-2 weeks after planting, weeding 4-5 weeks after planting, weeding 5-6 weeks after planting, 20 cm (intra-row) x 10 cm (inter-row), 30 cm (intra-row) x 10 cm (inter-row) and 40 cm (intra-row) x 20 cm (inter-row).

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