IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 9 Ser. III (September 2020), PP 17-24
www.iosrjournals.org

Effect of time of weeding and plant density on performance of a local variety of groundnut (*Arachishypogaea*L.) under rain-fed conditions in Ghana

Kwadwo Gyasi Santo[1], Joseph Sarkodie-Addo[2], Daniel Afreh Ntiamoah[3], Samuel Kwesi Asomaning[4]

[1, 3, 4] Department of Horticulture and Crop Production, School of Agriculture and Technology, University of Energy and Natural Resources, P. O. Box 214, Sunyani, Bono Region, Ghana
[2] Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, KNUST Post Office, Kumasi, Ghana
Corresponding author: Kwadwo Gyasi Santo

Abstract: *Field studies were undertaken at the Teaching and Research Farm, KNUST, in 2007 and 2008 to determine the effect of weeding and plant density on some yield attributes of Chinese Shitaochivariety of groundnut. The treatments were evaluated in a Randomized Complete Block Design with three replications. Groundnut seeds were planted at 250,000 plants/ha, 111,111 plants/ha and 74,740 plants/ha. Weeding levels included control (no weeding), weeding at 2-3 weeks after planting, weeding at 3-4 weeks after planting and weed-free. Dependent variables measured were number of seeds per pod, shelling percentage and hundred-seed weight.Weeding and plant density did not affect number of seeds per pod. Plant density did not affect hundred seed weight, but weeding significantly affected it in the major season of 2008, with weeding 2-3 weeks after planting and weed-free treatments recording the highest value of 41.7g. Weeding significantly improved shelling percentage irrespective of frequency of weeding. Shelling percentage was significantly influencedby plant density in the major seasons of the trial with the highest plant density recording the highest values of 69.70%, 71.40% and 74.10% in the major season of 2007, minor season of 2007 and major season of 2008, respectively. Groundnutsshould, therefore, beplanted at the highest plant density andkept weed-freeto increase grain yield. Future studies should include improved groundnut varieties, different plant densities and other tillage options in multi-seasons in different agro-ecologies.*

Keywords: ***groundnut, local variety, weeding, plant density, rain-fed conditions***

Date of Submission: 10-09-2020 Date of Acceptance: 25-09-2020

I. Introduction

Borget (1992) reported that the peanut is an annual herbaceous plant that grows to a maximum height of 60 cm and whose main and remarkable characteristic is the production of fruits underground. He established that groundnut has a variable growth habit since it could be erect, semi-erect and prostrate. Simpson and Ogorzaly (1995) reported that the Portuguese introduced groundnut into West Africa from Brazil in the 16th century. Groundnut has other names, namely peanut, monkey nuts, earthnuts, goobers, pincers (Williams *et al.*, 1989; Levetin and McMahon, 1999). The genus *Arachis* is South American in origin, and all species are located east of the Andes, South of the Amazon and North of the River Plate (Krapovickas, 1969; Gregory *et al.*, 1980; Norman *et al.*, 1996; Levetin and McMahon, 1999).

Groundnuts improve soil fertility by forming a symbiotic association with *rhizobia* that live in the root nodules and these *rhizobia* fix atmospheric nitrogen that becomes available to the groundnut plant. In exchange, the *rhizobia* also obtain carbohydrate from the groundnut plant. The groundnut plant could, therefore, grow more effectively in soils deficient in nitrogen than would non-legume plants do.

Kings (1966) noted that farmers in most parts of the tropics such as Ghana scarcely weed their crop farms. While all small-scale farmers recognize weeding as necessary, it does not rank high in the list of competing priorities of most of these farmers until the crop is nearly smothered by weeds. Yield loss caused by untimely weeding is, therefore, a hidden source of loss among peasant farmers and has its root in the traditional cropping system in which hand-weeding of all types are delayed until the weeds become a problem, by this time the damage has already been done (Akobundu, 1987).

Akobundu (1987) reported that a shortage of one growth factor creates imbalance that adversely affects the uptake and utilization of the other factors. Oudhia (2003) demonstrated that in the early stages of crop growth, legumes are poor competitors to weeds and the nature and magnitude of crop-weed competition is influenced by several factors such as crop species, cropping system, sowing time, plant population, moisture availability, and fertility conditions. Oudhia (2003) observed that in non-irrigated areas, the competition between weeds and crops is largely for water and a saving of 750 to 1,250 tonnes of water per hectare of soil, forming a one-metre deep column, was possible by keeping the soil free from weeds. He also noted that in irrigated tracts, the competition was severe for nutrients and that the mineral requirements of weeds were high. He supported this claim that the unchecked growth of weeds in a wheat field measuring one hectare, removed about 20 kg of nitrogen, which reduced grain yield. He also observed that weeds in a fallow land depleted the soils of both moisture and nutrients.

Work done by Lavabre*et al*. (1991) showed that in the tropics average crop losses due to weeds are estimated at 25%, but may be as high as 50% or even 80% with certain food crops. Weeds reduce yields by competing directly for the resources of the environment and inputs in terms of water, nutrients, space and light. Where the weeds are abundant and grow faster than the crop plants, they may choke up the crop. In an attempt to keep pace with the fast growing weeds, the crop may grow tall, lean and weak or etiolated and finally give poor yields. Some weeds even utilize cultivated crops for support and strangle them to death. This competition adversely affects growth and development of crops. The ability of the weeds to compete with cultivated crops depends on their root system, height, leaf area, density and frequency of occurrence.

Plant density is highly associated with yield potential and optimum plant density per unit area is an important non-monetary input to decide the maximum groundnut productivity. Yield is a function of inter-plant and intra-plant competition, and there is a considerable scope for increasing the yield by adjusting plant population to an optimum level. Donald (1963) suggested that the high seed weight and number of seeds per inflorescence at intermediate densities could be due to the timing of inter-plant and intra-plant competition. At the lowest plant density, both types of competition may be absent during early stages of growth. Under unfavourable environments, narrowing the rows of most crop plants will not increase yield. 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. Again, farmers plant on mounds, ridges or randomly without any defined rows, thus not obtaining the required optimum plant population and hence lower yields.

The study was, therefore, carried out to determine the effect of weeding and plant density on some yield attributes of Chinese Shitaochivariety of groundnut. Specifically, the objective of the study was to determine the effect of weeding and plant density on shelling percentage, hundred seed weight and number of seeds per pod of groundnut under natural conditions.

II. Materials and Methods

2.1 Experimental site

The experiment was conducted at Kwame Nkrumah University of Science and Technology, Kumasi (6’35N - 6’40N and 1’30W-135W with an elevation of 250m- 300m above sea level) in the Ashanti Region of Ghana from April, 2007 to July, 2008. The Region falls within the equatorial climate zone with a bimodal rainfall regime. The major season rains occur from mid-March to the end of July with a peak fall in June. The minor season rains extend from September to mid-November with a peak fall in October at which period dry desiccating harmattan winds blow across the area from the north. The rainfall regimes are partitioned by a period of dry weather from December to March. The area also has a mean temperature range of $21^{o}C$ to $30^{o}C$ (Meteorological Department of Kumasi Metropolitan Assembly – KMA, Kumasi, 2007). The soil belongs to the Kumasi series, which is locally classified as Ochrosols or Ferric Acrisol. The soil is moderately shallow, red, well-drained, light clay and occurs at upper slopes.

2.2 Chemical properties of soil

The experimental site had a pH of 5.6, 1.36% of organic carbon, 2.34% of organic matter, 0.10% of nitrogen, 0.36 Cmol/kg/Me/100g of potassium, 4.40 Cmol/kg/Me/100g of calcium, 2.00 Cmol/kg/Me/100g of magnesium and 20.00 ppm of phosphorus (Table 1).

Table 1: Chemical properties of soil samples (30cm depth) from experimental sites

Nutrient	Level
pH	5.6
Organic carbon (%)	1.36
Organic matter (%)	2.34
Nitrogen (%)	0.10
Potassium (Cmol/kg/Me/100g)	0.36
Calcium(Cmol/kg/Me/100g)	4.40
Magnesium (Cmol/kg/Me/100g)	2.00
Phosphorus (ppm)	20.00

Soil Research Institute, Kumasi (2007)

2.3 Climatic conditions at experimental site

In 2007, the highest rainfall amount of 539.8mm was recorded in September, while the lowest rainfall amount of 2.9mm was recorded in December. In 2008, the highest rainfall amount of 185.8mm was recorded in May, while the lowest rainfall amount of 0.00mm was recorded in January. In 2007, the highest average temperature of 28.9 °Cwas observed in March, whereas the lowest average temperature of 22.1 wasnoticed in January. In 2008, the highest averagetemperature of 28.4 °Cwas observed in March, whereas the lowest average temperature of 25.2 °C wasnoticed in August (Table 2).

Table 2: Climatic data during the growth period of 2007 and 2008

Month	Rainfall (mm)		Temperature (°C)	
	2007	2008	2007	2008
January	8.5	0.0	22.1	26.3
February	65.3	61.7	28.5	28.2
March	76.7	134.1	28.9	28.4
April	189.9	117.1	28.3	28.1
May	84.3	185.8	27.7	27.9
June	244.2	179.8	26.6	27.0
July	374.0	45.0	25.3	25.6
August	127.3	114.5	24.8	25.2
September	539.8	148.9	26.9	25.7
October	237.6	95.8	26.3	26.5
November	48.6	30.7	26.6	27.5
December	2.9	47.5	26.8	26.6

Meteorological Department of Kumasi Metropolitan Assembly, Kumasi (2007)

2.4 Experimental Design and Treatments

Fourlevels 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 plant densities including 250,000 plants/ha (S1), 111,111 plants/ha (S2)and 74,740 plants/ha (S3) were evaluated in a Randomized Complete Block Design with three replicates.

2.5 Planting and cultural operations

A two-year fallowed land from cassava cultivation was ploughed and disc-harrowed two weeks after ploughing with a tractor. The field was completely prepared into plots, each measuring 2.7m (intra-row) x 4.5m (inter-row) with 1m between plots and 2m between blocks. In all, there were thirty six plots in each of the three trials carried out. The area of the experimental field for each of the three trials was 656.5m^2. Seeds of Chinese Shitaochivariety of groundnut were obtained from the CSIR-Crop Research Institute (CRI), Kumasiand were tested for viability by percentage germination test. One hundred seeds were randomly selectedfrom the seed lot and were planted in a shallow furrow and covered with a thin layer of soil. Two weeks after planting, the number of germinated seedlings was counted. The percentage germination was calculated by expressing the germinated seedlings as a percentage of the hundred seeds sown. The percentage germination of 90%was accepted for planting. Groundnut seeds were planted with two seeds per hill on 29th April, 2007, 15th August, 2007 and 2nd May, 2008 in experiments 1, 2 and 3, respectively. Seeds were sown at 20cm x 20cm, 30cm x 30cm and 30cm x 45cm for the highest, intermediate and lowest plant densities, respectively.

Filling of vacancies was done seven days after planting. Seedlings were thinned to one plant per stand fourteen days after germination. Single superphosphate at a rate of 50 kg/ha was applied one month after planting by side dressing. Rodents were serious pests during the experiment and scare-crows were, therefore, used to ward them off. Weeds were managed as per the treatments imposed. Thus, plots with treatment W0 were not weeded throughout the study; plots with treatment W1 were weeded 2 -3 weeks after planting; plots with treatment W2 were weeded 3-4 weeks after planting and plots with treatment W3 were kept weed-free throughout the experiment.

Harvesting was done at physiological maturity on 5th August, 2007, 25th November, 2007 and 24th July, 2008 for experiments 1, 2 and 3, respectively.

2.6 Data collected

Shelling percentage was obtained by expressing seed weight as a percentage of pod weight.After hand-shelling, the total number of seeds per plant was divided by the mean number of well-filled mature pods per plant to obtain number of seeds per pod. Three seed lots were counted randomly from each of the treatments and their 100-seed weights taken using an electronic balance. The average of the three seed lots was subsequently weighed.

2.7 Data analysis

The data were subjected to ANOVA with the Genstat Statistical package (Payne *et al*., 2009). LSD at p-value of 0.05 was used to separate treatment means.

III. Results

3.1 Shelling percentage

No-weeding treatment gave a shelling percentage which was significantly ($P<0.05$) the lowest and differed from the other weeding treatments in both seasons of 2007. All other weeding treatment means were similar.The highest shelling percentage was associated with weeding 2-3 weeks after planting, weeding 3-4 weeks after plantingand weed-free in both trials of 2007. Plant density had no significant ($P>0.05$) influence on shelling percentage in the minor season of 2007, but significantly influenced shelling percentage in the major season of 2007. In the major season of 2007, there was no significant difference between the highest and lowest plant densities in terms of shelling percentage. Again, the intermediate plant density did not vary from the lowest plant density, but differed significantly from the highest plant density. The highest plant densitygave the highest shelling percentage in both seasons of 2007, while the lowest shelling percentage was obtained in the intermediate plant density in the major season of 2007 and the lowest plant density in the minor season of 2007(Table 3).

Results of shelling percentage showed a significant effect ($P<0.05$) with treatment application in the major season of 2008. The weeding 3-4 weeks after planting treatment and the highest plant density gave the highest values(Table 3).The least shelling percentage was observed in the no-weeding treatment and the lowest plant density.Plants from plots which were not weeded differed from those which were weeded at 2-3 and 3-4 weeks after planting, but were similar to plants from plots which were kept weed-free. Plants from plots which were weeded at 2-3 and 3-4 weeks after planting were similar in terms of shelling percentage, but both varied from plants produced from plots which were kept weed-free throughout the trial. The intermediate and lowest plant densities did not vary from each other, but both differed significantly from the highest plant density which recorded the highest shelling percentage.

Table 3: The effect of weeding and plant density on shelling percentage of groundnut in 2007 major and minor seasons and 2008 major season

Treatment	Shelling percentage (%)		
	2007 major season	2007 minor season	2008 major season
Weeding (W)			
W0	55.80a	57.10a	65.64a
W1	68.40b	73.90b	74.84b
W2	68.40b	71.60b	75.12b
W3	64.20b	76.10b	68.59ac
LSD (5%)	7.16	7.02	4.93
Plant density (S)			
S1	69.70a	71.40a	74.10a
S2	59.60b	69.90a	69.96b
S3	63.30b	67.80a	69.09b
LSD (5%)	6.20	NS	4.27
W x S interaction	NS	NS	NS
CV (%)	11.40	10.30	7.10

NS: Not significant

3.2 Number of seeds per pod and hundred-seed weight

Number of seeds per pod was not significantly affected ($P>0.05$) by weeding and plant density in both seasons of 2007 (Table 4) and the major season of 2008 (Figures 1a and 1b). No clear trend was established by the treatments imposed.

Plant density did not have any significant influence ($P>0.05$) on hundred seed weight in all the three cropping seasons of the trial. Hundred seed weight responded significantly ($P<0.05$) to weeding in 2008 (Figures 2a and 2b), but was not significantly affected ($P>0.05$) by weeding in both seasons of 2007 (Table 5). The highest hundred-seed weight in 2008 was shown in the weed-free, weeding 2-3 weeks after planting treatments and the lowest plant density, while the no-weeding and the intermediate plant density produced the lowest values (Figures 2a and 2b). The results of hundred-seed weight in 2008 showed that plants from plots which were not weeded throughout the studyvaried significantly from the other plots which were weeded irrespective of time of weeding. Weeding 2-3 and 3-4 weeks after planting and weed-free treatments did not vary in hundred-seed weight.

Table 4: The effect of weeding and plant density on number of seeds per podof groundnut in 2007 major and minor seasons

Treatment	Number of seeds per pod	
	2007 major season	2007 minor season
Weeding (W)		
W0	2.06a	2.08a
W1	1.99a	2.13a
W2	1.98a	2.03a
W3	2.02a	2.06a
LSD (5%)	NS	NS
Plant density (S)		
S1	2.01a	2.11a
S2	2.00a	2.04a
S3	2.03a	2.08a
LSD (5%)	NS	NS
W x S interaction	NS	NS
CV (%)	6.60	6.40

NS: Not significant

Table 5: The effect of weeding and plant density on hundred-seed weight of groundnut in 2007 major and minor seasons

Treatment	Hundred-seed weight (g)	
	2007 major season	2007 minor season
Weeding (W)		
W0	31.89a	30.81a
W1	31.84a	31.18a
W2	31.97a	31.20a
W3	31.92a	31.77a
LSD (5%)	NS	NS
Plant density (S)		
S1	31.64a	31.14a
S2	31.84a	31.39a
S3	32.18a	31.20a
LSD (5%)	NS	NS
W x S interaction	NS	NS
CV (%)	5.10	2.10

NS: Not significant

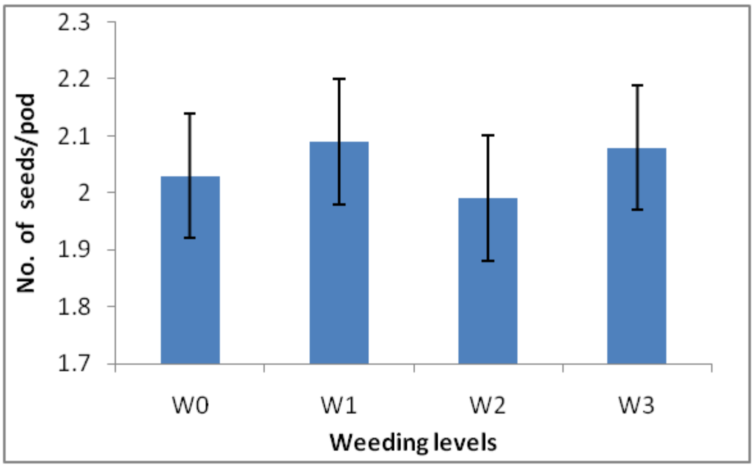

Figure 1a: The effect of weeding on number of seeds per pod in the major season of 2008

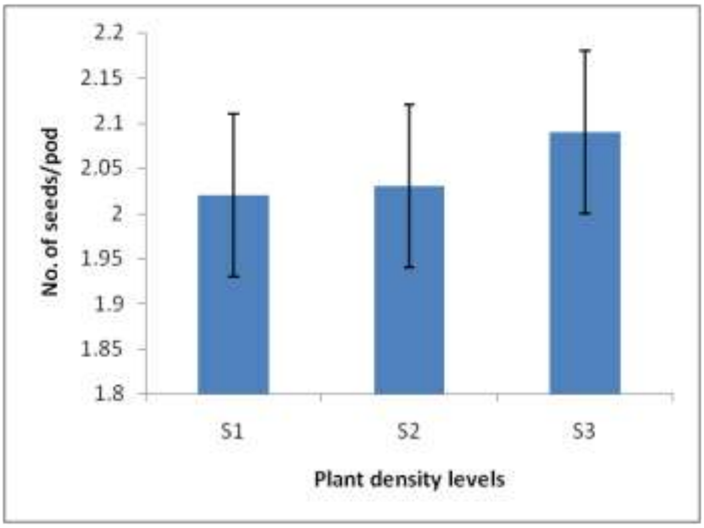

Figure 1b: The effect of plant density on number of seeds per pod in the major season of 2008

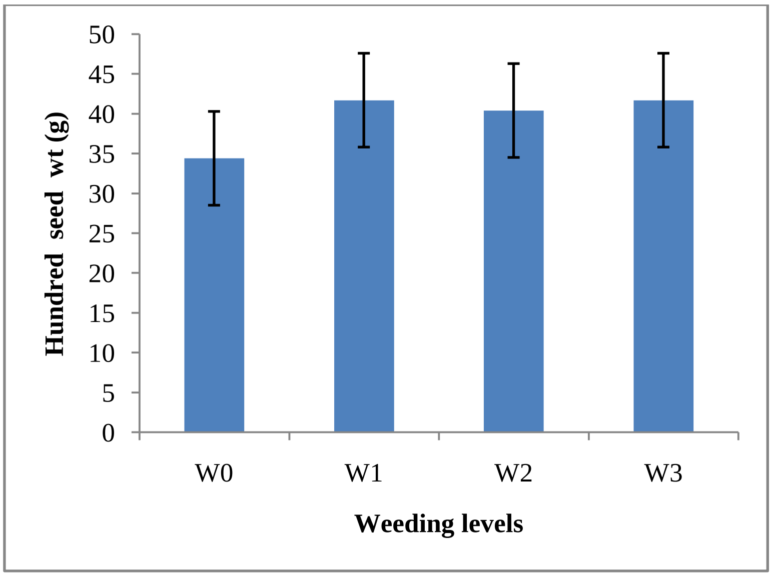

Figure 2a: The effect of weeding on hundred seed weight in the major season of 2008
LSD at 5% was 5.89.

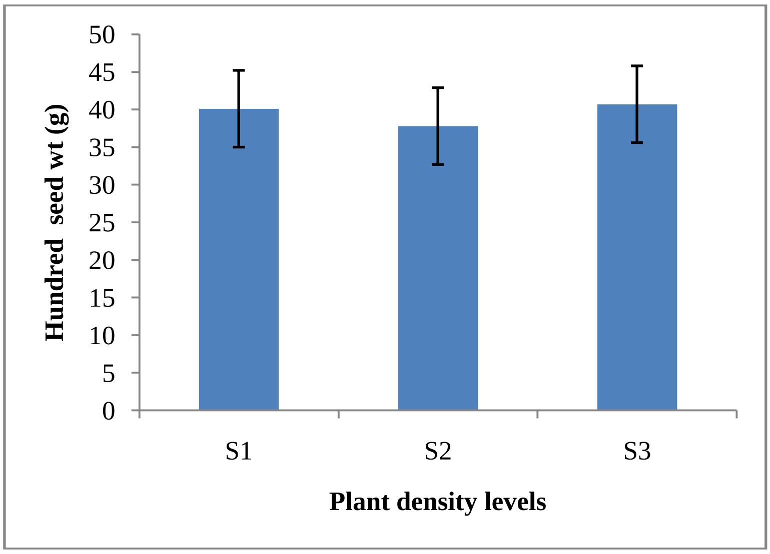

Figure 2b: The effect of plant density on hundred seed weight in the major season of 2008

IV. Discussion

4.1 Shelling percentage

Shelling percentage is an index of crop yield and it indicates the proportion of the total dry matter synthesized that has been allocated to the seeds. According to Ramesh and Sabale (2001), this parameter is affected by varietal and environmental factors affecting photosynthesis, dry matter accumulation and partitioning. Results showed that imposition of weeding treatments significantly ($P<0.05$) increased shelling percentage over the control treatment (Table 3), indicating that weeding generally influenced shelling percentage irrespective of the frequency of weeding. The higher shelling percentage recorded by the weeding treatments could be due to reduced mining of resources, maintenance of optimal temperature, decreased incidence of pests and diseases and efficient allocation of assimilates. The results also showed that the highest plant density recorded the highest shelling percentage in the experiment. This could be attributed to reduced weed growth and lower competition for resources, leading to improved dry matter partitioning. Moreover, results indicated that the 2008 trial recorded a higher shelling percentage than the 2007 trials due to favourable rainfall amount and distribution and better soil-water relations (Table 2).

4.2 Number of seeds per pod

Number of seeds per pod was not influenced by weeding and plant density. Number of seeds per pod is a varietal characteristic, controlled largely by plant genetic factors (Ogundele, 1988). However, weeding 2-3 weeks after planting treatment recorded the highest number of seeds per pod in the minor season of 2007 (Table 4) presumably due to low competition for resources. Although plant density did not affect the number of seeds per pod, the highest plant density marginally had the highest value of 2.11 in 2007 minor season probably due to efficiency of dry matter partitioning in that treatment. Results obtained in the trials collaborate with the work of Norman *et al*. (1996) who observed that at the highest plant density, relatively few number of pods per plant were produced which could increase the number of seeds per pod. Generally, the minor season of 2007trial had the highest number of seeds per pod because of higher rainfall and adequate temperature (Table 2) recorded during the period of pod filling.

4.3 Hundred-seed weight

Though weeding did not influence hundred-seed weight in both seasons of 2007, it affected hundred seed weight in 2008 major season. Results showed that hundred-seed weight marginally increased in the weeding treatments over the control (Table 5) presumably due to lower competition for resources, leaf retention and efficiency of dry matter partitioning in the former. Hundred-seed weight was not influenced by plant densityin both 2007 and 2008. However, the highest hundred-seed weight was associated with the lowest and the intermediate plant densities. The results may be due to sufficient space between rows, lesser interplant competition for resources, which resulted in an efficient dry matter partitioning, leading to heavier individual seed sizes and weights. The results agree with work of Sathyamoorthi *et al.*(2007)who observed that at the lowest plant density, sufficient moisture and lesser competition led to efficient dry matter partitioning.

Hundred-seed weights were comparatively high in the 2008 major season trial. This could be caused by the early incidence of drought (Table 2) that hindered subsequent flowering and podding so that eventually only sinks which were formed earlier were available for pod filling. Efficient dry matter partitioning and suitable soil conditions could also contribute to the results. Norman *et al.* (1996) observed that drought in the early reproductive stage reduced flowering and this agrees with the findings of the present study. The range of mean seed weight (31.24g - 39.50g) obtained in the trials was lower than the 67g to 70g obtained by Frimpong*et al.* (2006), but was consistent with that reported by Borget (1992) with an average seed weight range of 30-50 g.

V. Conclusion and Recommendation

5.1 Conclusion

Results of the study showed that weeding and plant density did not affect number of seeds per pod.Plant density did not affect hundred seed weight, but weeding significantly affected it in the major season of 2008, with weeding 2-3 weeks after planting and weed-free treatments recording the highest.Weeding significantly improved shelling percentage irrespective of frequency of weeding.The highest plant densitysignificantly gave the highest shelling percentage throughout the study.

5.2 Recommendation

Shelling percentage is an index of crop yield and it indicates the proportion of the total dry matter synthesized that has been allocated to the seeds. Groundnutsshould, therefore, be closely planted and kept weed-free to increase grain yield as the highest plant density and weed management irrespective of frequency of weeding maximized shelling percentage. Future studies should include improved groundnut varieties, different plant densities and other tillage options in multi-seasons in different agro-ecologies.

References

[1]. Akobundu, I.O. (1987). Weed science in the tropics, John Wiley and Sons Limited, Britain.

[2]. Borget, M. (1992). Tropical Agriculturalist: Food Legumes. CTA Macmillan. 103pp.

[3]. Donald, C.M. (1963). The interaction of competition for light and nutrients. *Aust. J. agric. Res*., 9:421-435.

[4]. Frimpong, A., Padi, F.K. and Kombiok, J. (2006) (SARI). Registration of Foliar Disease Resistant and High-Yielding Groundnut Varieties ICGV 92099 and ICGV 90084.

[5]. Gregory, W.C., Krapovickas, A. and Gregory, M.P. (1980). Structure, variation, evolution and classification in *Arachis*. In: Advances in Legume Science, R.J. Summerfield and A.H. Bunting, pp. 469-81. Kew: Royal Botanic Gardens.

[6]. Kings, J.L. (1966). Weeds of the world. London Leavnard Hill Inter Science pub. Inc, New York.

[7]. Krapovickas, A. (1969). The Origin, Variability, and Spread of the Groundnut (*Arachishypogaea*). In: The Domestication and Exploitation of Plants and Animals. P.J. Ucko and J.W. 3:20-38.

[8]. Kumasi Metropolitan Assembly – KMA (2007). Development Plan for Kumasi Metropolitan Assembly (2006-2009). GOG, Ministry of Local Government, Rural Development and Environment, KMA. Incomplete Document. 265pp.

[9]. Kvien, C.S. and Bergmark, C.L. (1987). Growth and development of the Florunner peanut cultivar as influenced by population, planting date and water availability, *Peanut Science*, 14:11-16.

[10]. Lavabre, E.M., Wibberley, J. and Deat, M. (1991). Weed control. The Tropical Agriculturalist sense, Mcmillan (London), pp 1-2.

[11]. Levetin, E. and McMahon, K. (1999). Plants and Society 2nd Edition. WCB/McGraw-Hill Madrid. 477pp.

[12]. Norman, M.J.T., Pearson, C.J. and Seale, P.G.E. (1996). Tropical Food Crops in their environment. 2nd Edition. Cambridge University Press. Cambridge. 430pp.

[13]. Ogundele, B.A. (1988). Variability for seedling vigour in cowpea evaluated in South Western Nigeria. *Genetic Agraria*, 42(2):133-140.

[14]. Oudhia, P. (2003). Allelopathic effects of weeds on crops. *Research Journal of Agriculture and Biological Sciences*, 3(1):52-58.

[15]. Payne, R.W., Murray, D.A., Harding, S.A., Baird, D.B., Soutar, D.M. (2009). Genstat for Windows (12th Edition) Introduction. VSN International, Hemel Hempstead.

[16]. Ramesh, R. and Sabale, R.N. (2001). Phosphorus and plant population management in groundnut (*Arachishypogaea*) – fenugreek (*Trigonellafoenum – graecum*) cropping system. *Indian J. Agron*., 46(4):621-626.

[17]. Sathyamoorthi, I.K., Chandrasekaran, R., Somasundaram, E., Mohamed-Amanullah, M. and Thirukumaran, I.K. (2007). Influence of Varieties and Plant Spacing on the Growth and Yield of Confectionery Groundnut (*Arachishypogaea*L.). *Research Journal of Agriculture and Biological Sciences*, 3(5):525-528.

[18]. Simpson, B.B. and Ogorzaly, M.C. (1995). Economic Botany: Plants in our World. 504 pp.

[19]. Soil Research Institute, Kumasi (2007).Guide to interpretation of soil analytical data.

[20]. Williams, C.N., Chew, W.Y., Rajaratnam, J.H. (1989). Field and Tree Crops of the Wetter Regions of the Tropics (ITAS), Longman Scientific Group, London. 262pp.