KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES
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DEPARTMENT OF CROP AND SOIL SCIENCES

GROWTH AND YIELD RESPONSE OF GROUNDNUT (*Arachis hypogyaea* L.) TO WEEDING REGIME AND PLANT SPACING

A THESIS SUBMITTED TO THE DEPATMENT OF CROP AND SOIL SCIENCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE (AGRONOMY)

BY

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Declaration

I do hereby declare that this submission is the outcome of my own effort and that in no previous application for a similar degree in Master of Science (Agronomy) in this University or elsewhere has this work been presented, except where due acknowledgement has been made in the text.

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(Supervisor)	Signature	Date

Dedication

This work is dedicated to the Almighty God, my dearest wife, Mrs. Georgina Amobea Santo and sons, Benedict Owusu Santo and Franklin Donkor Santo, my parents, Mr. William Donkor and Ms. Philomina Donkor, uncles, aunties, siblings, cousins and friends.

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My sincere gratitude and appreciation to the Almighty God whose Grace has seen me through my education peacefully and has also made it possible for me to bring this programme of study to a fruitful completion. To him be all the glory.

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ABSTRACT

Field experiments were conducted at the Plantation Section of the Faculty of Agriculture, KNUST, in the major (March) and minor (August) seasons of 2007 and major (May) season of 2008 to determine the growth and yield response of groundnut to weeding regime and plant spacing. 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 W3 or weed-free) and three levels of plant spacing which included 20 cm x 20 cm (250,000 plants/ha), 30 cm x 30 cm (111,111 plants/ha) and 30 cm x 45 cm (74,740 plants/ha)). Normal husbandry treatments including refilling, thinning, fertilizer application, pests and disease control and weeding were undertaken. Response variables measured were growth and yield components.

The results of the study indicated that the weed-free treatment significantly ($P<0.05$) recorded the highest plant height, shoot dry matter, number of branches and nodules per plant. The results also showed that total dry matter, pod and grain yields, number of pods per plant, shelling percentage and harvest index showed significant response ($P<0.05$) to weeding in both 2007 and 2008. However, the number of seeds per pod did not show any significant effect with weeding in all the three seasons. Similarly, weeding did not significantly ($P>0.05$) affect hundred seed weight in 2007, but had significant effect ($P<0.05$) on hundred seed weight in 2008.

The highest grain yields of 1034 kg ha^{-1}, 1231 kg ha^{-1} and 3579 kg ha^{-1} were produced by the weed-free treatment in March, 2007, August, 2007 and May, 2008, respectively, and were mainly due to the increased number of pods per plant and hundred seed weight.

Results of the three seasons indicated that total dry matter, pod and grain yields and number of pods per plant were influenced by plant spacing. However, number of seeds per pod, hundred seed weight and harvest index did not show any significant effect ($P>0.05$) with spacing in all the seasons.

The widest spacing (30cm x 45cm) significantly ($P<0.05$) gave the highest plant height, number of branches, number of nodules, shoot dry matter and number of pods per plant in all the three seasons. The closest spacing (20cm x 20cm) recorded the highest total dry matter, pod and grain yields, shelling percentage, and harvest index, with the highest grain yields being 969 kg ha^{-1}, 967 kg ha^{-1} and 3449 kg ha^{-1} in March, 2007, August, 2007 and May, 2008.

The weeding treatment showed that total dry matter was positively correlated with seed yield ($r=0.948$), number of pods per plant ($r=0.972$), number of seeds per pod ($r=0.957$) and hundred seed weight ($r=0.667$). Similarly, total dry matter had positive correlation with seed yield ($r=0.972$), number of seeds per pod ($r=0.920$), but negatively correlated with hundred seed weight ($r=-0.911$) and number of pods per plant ($r=-0.922$) with spacing treatment.

Farmers should adopt the weed-free and the closest spacing treatments since they produced the highest pod and grain yields in the experiment of all the three seasons.

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Abbreviations, Acronyms and Symbols

ANOVA	Analysis of Variance
AUG	August
CRI	Crop Research Institute
CSIR	Council for Scientific and Industrial Research
CV	Co-efficient of Variation
FAO	Food and Agriculture Organization

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
KNUST	Kwame Nkrumah University of Science and Technology
LSD	Least Significant Difference
MAR	March
MOFA	Ministry of Food and Agriculture
RMRDC	Raw Materials Research and Development Council
S1	Spacing of 20 x 20cm
S2	Spacing of 30 x 30cm
S3	Spacing of 30 x 45cm
SRI	Soil Research Institute
TDMP	Total Dry Matter Production
TDMY	Total Dry Matter Yield
WAP	Weeks After Planting
W0	No weeding
W1	Weeding 2-3 weeks after planting
W2	Weeding 3-4 weeks after planting
W3	Weed-free (weeding when necessary)

CHAPTER ONE

1.0. INTRODUCTION

Groundnut (*Arachis hypogaea*) is a day neutral, leguminous annual herbaceous oil seed crop. It belongs to the Papilionoideae sub-family of the family Leguminosae (Norman *et. al*., 1996). Groundnut 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, 1968; Gregory *et al*., 1980). The cultivated groundnuts were introduced into Africa and West Africa by the Portuguese in the sixteenth century (Waele and Swanvelder, 2001).

Groundnut production in Ghana has nearly tripled in the last decade (168,200 t in 1995 to 420,000 t in 2005) primarily due to increases in the area under cultivation which increased from 180,400 in 1995 to 450,000 ha in 2005 (FAO, 2006). Average yields, however, continue to remain below 1.0 t ha^{-1} which is far below the potential yields of 2.0-3.0 t ha^{-1}. 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 grown in nearly 100 countries. Major groundnut producers in the world are China, India, Nigeria, USA, Indonesia and Sudan. Developing countries account for 96% of the global groundnut area and 92% of the global production. Asia accounts for 58% of the global groundnut area and 67% of the groundnut production with an annual growth rate of 1.28% for area, 2.00% for production and 0.71% for productivity (FAO, 2004).

Groundnut is an important food crop of the world. All parts of the peanut plant can be easily utilized. Beside income for farmers, groundnut provides an inexpensive source of high quality dietary protein and edible oil. The vast food preparations incorporating groundnut to improve the protein level has helped in no small way in reducing malnutrition in the developing countries. The special taste and flavour of foods containing groundnut is important in the acceptance of these food preparations. It is estimated that the shell represents about 25% of the dry weight of unshelled peanut, and the kernel comprises 75%. Groundnut seeds contain high quality edible oil (50%), easily digestible protein (25%), carbohydrates (20%), vitamin E, niacin, folacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium (FAO, 2004). Worthington and Hammons (1971) reported that the seed has several uses as whole seed or processed to make peanut butter, oil, soups, stews and other products. Nearly two thirds of all groundnuts produced are crushed for oil (Bunting *et al.*, 1985). Oil is the most important product of groundnut. Oil from unshelled nuts is preferred due to less risk of the oil turning rancid and low incidence of *Aspergillus flavus* infestation. Groundnut oil is used as fuel in diesel engines and lighting and also in the manufacture of peanut butter, margarine, furniture creams, salad oils, soaps and cooking oil and for cooking sardines before packing them in olive oil. The groundnut cake obtained after oil extraction and groundnut haulms are useful animal feeds. The cake is also used in infant food formulations. Groundnut protein is increasingly becoming important as food and feed sources, especially in developing countries where protein from animal sources are not within the means of the majority of the populace. The peanut is well-established snack food as fresh, cooked and roasted peanuts (Williams *et al*., 1989; Levetin and McMahon, 1999). The leaves and stems (haulms) can also be ploughed into soil or prepared into silage for feeding animals. The shells or pods can be used as feed for livestock, burned for fuel, made into particle board, and many other uses (Williams *et al*., 1989; Levetin and McMahon, 1999; FAO, 2004).

Groundnuts improve soil fertility by forming symbiotic association with *rhizobia* which live in the root nodules and they fix atmospheric nitrogen which 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.

Groundnut cultivation is influenced by a number of factors such as climatic factors like rainfall, temperature, humidity, wind, solar radiation, edaphic (soil factors) and biological factors such as pests and diseases and agronomic factors such as spacing and weed management. For instance, high cost of weeding, scarcity of labour to weed, late weeding due to social functions like funerals, marriage ceremonies reduce groundnut yields. Again, farmers plant on mounds, ridges or randomly without any defined rows, thus not obtaining the required optimum plant population and hence lower yields. Plant spacing plays an important role in canopy development and weed control.

Therefore, there is the need to research into agronomic practices such as weeding and spacing to improve upon the growth and yield of groundnuts so as to attract farmers to its cultivation.

Poor and untimely land preparation may cause serious weed problems and may lead to erosion (Frederick, 1985). According to Sinnadurai (1992), soil surface that is fairly smooth and free from clods promotes planting of seed at uniform depth and also gives good soil coverage. He further observed that land preparation is a fundamental practice of crop production in working soil by hoeing, ploughing, harrowing and cultivation.

According to Akobundu (1987), weeds are a major problem for farmers in the tropics. Akobundu

(1987) observed that the subsistence nature of the tropical farming and the drudgery that characterize peasant agriculture are principally due to the presence of weeds and the absence of improved methods of controlling them.

Weeds are the most underestimated serious crop pests in the tropics. Various studies carried out to determine components of early weed interference in crops showed that moisture is implicated early during the first three weeks after emergence in weed-crop competition before other growth factors becoming limiting (Sweet and Minotti, 1980). Akobundu (1987) and Youdeowei (2002) indicated that weeds acted as hosts to pests and harbour many fungal, viral and bacterial diseases. The International Institute of Tropical Agriculture (IITA, 1997) showed that uncontrolled weeds reduced yields of semi prostrate and erect crops by 68% and 78% respectively. However, farmers in most parts of the tropics and Ghana in particular, scarcely weed their crop farms (Kings, 1966). 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 covered 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 (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.

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 greater seed weight and number of seeds per inflorescence at intermediate densities are due to the timing of inter-plant and intra-plant competition. At the widest spacing (lowest plant density), both types of competition are absent during early stages of growth. Under unfavourable environments, narrowing the rows of most crop plants will not increase yield. Taylor (1980) tested the hypothesis that during years of lower water supply soybean grown in wide rows would yield as much as or more than soyabean grown in narrow rows. In a season of high water supply, seed yield in narrow (25cm) rows yielded 17% more than in 100cm rows. 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 response of groundnuts to different spacing.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Taxonomy of groundnut *(Arachis hypogaea* Linnaeus*)*

The genus *Arachis*, the taxonomy of which is described by Gregory and Gregory (1976), Gregory *et al*. (1980) and Smartt (1990) includes 37 named species and a number of undescribed species. The groundnut, *Arachis hypogaea* **L**., is within the section *Arachis*, one of the seven into which the genus has been divided. The section *Arachis* comprises annual and perennial diploids (2n = 2x = 20) and two annual tetraploids (2n = 4x = 40), one of which is the cultivated *Arachis hypogaea*. Branching and floral axis patterns are the primary discriminating characters for classifying genotypes within the species.

The grouping of Krapovickas (1973), which is generally accepted, puts groundnuts into two subspecies, namely, subspecies *hypogaea* and subspecies *fastigiata*. Subspecies *hypogaea* have no floral axis on main stem and there are no alternating pairs of vegetative and floral axes on laterals. These include var. *hypogaea* which is less hairy and has short branches (Virginia type) and var. *hirsuta* which is more hairy and has long branches (Peruvian Runner type). Subspecies *fastigiata* have floral axes on main stem and there is continuous run of floral axes on laterals. These include var. *fastigiata* which is little branched (Valencia type) and var. *vulgaris* which is more branched (Spanish type).

2.2. Origin and distribution

The archaeological records support its cultivation between 300 and 2500 BC in Peruvian desert oases (Weiss 2000, Smith 2002). 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). *Arachis hypogaea*

L. is cross-compatible with all diploid species within the section *Arachis*, forming infertile or partially fertile triploids. Gregory *et al*. (1980) believed that it originated as a wild allotetraploid of two species in the section *Arachis,* somewhere along the Eastern front of the Andes. According to Krapovickas (1969), cultivated groundnuts were widely spread/ dispersed through South and Central America by the time Europeans reached the continent probably by the Arawak Indians and there was an archaeological evidence in Mexico, 1300-2200 BP. He also observed that it was, therefore, not surprising that, after European contact, more than one major genotype was dispersed around the world. He further said that the Peruvian runner type was taken to the Western Pacific, China, South East Asia and Madagascar (now Malagasy Republic).

According to him, the Virginia type was probably introduced to Mexico (and then across the Pacific via the Philippines) by the Spanish in the sixteenth century and it was then taken to Africa, and later India, via Brazil by the Portuguese. Again, Krapovickas (1969), noted that the Virginia types apparently reached South East USA with the slave trade and the Spanish type was introduced to the Old world by the Portuguese in the eighteenth century. Gibbon *et al*. (1972) noted substantial secondary diversity in Africa and Asia. The types they found and their locations generally support the above conjectures regarding dispersal. Simpson and Ogorzaly (1995) reported that the Portuguese were responsible for its introduction into West Africa from Brazil in the sixteenth century. Groundnut has other names namely, peanut, monkey nuts, earthnuts, goobers, pincers (Williams *et al*., 1989; Levetin and McMahon, 1999).

2.3. Botany or Morphology

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 (subterranean fruiting). He established that groundnut has a variable growth habit since it could be erect, semi-erect and prostrate. Ramanatha (1988) noted that the stems are generally angular or round, pubescent or hairy and solid with short internodes and large central pith in the early stages. He added that though the main stem height depends on genotype, it is influenced by environment to a considerable degree and ranges from 12cm to 65cm.

Stem thickness is highly variable, although Ramanatha (1988) reported that generally the bunch types have thicker internodes, short and highly condensed at the base and longer at the higher nodes. The basal stem diameter could be as much as 8cm in some of the wild species. Williams *et al*. (1989) found that the stem of groundnut has many low branches that bear four leaflets.

Borget (1992) noted that the leaflets have a dimension of 3-7cm and 2-3cm. Mouli and Kale, (1982) observed earlier that the leaves are tetrafoliate except in species belonging to the section trifoliolatae which have three leaflets. They further stated that leaflets are opposite, subsessile, elliptic (variable) and shortly mucronate with entire ciliate margin. Simpson and Ogorzaly (1995) revealed that the flowers of groundnuts are pea-like. Work done by Ono (1979) indicated that the flowers are sessile but appear stalked after the growth of a tubular hypanthium just before anthesis and may arise from the leaf axils closer to the base of the stem. His report also showed that the most prolific flowering occurs between 5 and 11 weeks after planting, depending on the duration of the cultivar and the season, with a high degree of first-formed flowers producing mature fruits.

Chapman *et al*. (1993) indicated that groundnut produces more flowers than the plant can sustain to develop into pods and about 40% of the flowers fail to develop from the outset, while another 40% produce only pegs. According to Donovan (1963), less than 20% of the flowers produce mature fruit under best conditions and Lim and Hamdan (1984) reported that sometimes less than 15% of the flowers produce mature fruit under best conditions. They found that genotypes which flower early show greater synchrony and those which produce most of the flowers during the first two weeks of the flowering period produce greater number of pods. Work done by Chapman *et al*. (1993) revealed that the removal of some flowers every day can prolong flowering. Smith (2000) established that both subspecies of groundnut feature indeterminate axillary branch and flower formation and the production of subterranean (underground) fruit. Kowal and Kassam (1978) reported that the ovary is formed from a single carpel and contains up to 5 ovules. They indicated that the flowers of groundnut are cleistogamous and, therefore, self-fertilized and after anthesis (syngamy) the ovary elongates and forms a peg or carpophores.

Kowal and Kassam (1978) found that the peg grows most rapidly 5-10 days after anthesis and there is then a period of rapid cell division in the embryo and the peg grows downward (freely positively geotropic) and enters the soil at 8-16 days after anthesis. Furthermore, they found that the elongation of the peg stops after it has penetrated to about 5-7 cm and the apical region then swells, bends through 90^0 and enlarges into a pod which differentiates into seeds (nuts) and shell. Choudhari *et al.* (1985) stated that the pegs originating from points high up on the stem (>15 cm above soil level) may fail to reach and penetrate the soil and will dry up. Sometimes the soil may be too dry and peg may again fail to penetrate. Choudhari *et al.* (1985) observed that some farmers try to reduce the distance the peg would have to grow by stepping on the erect stems to lodge them a bit or heaping some soil underneath the plant while weeding (earthing up). Choudhari *et al.* (1985) indicated that indeterminacy and subterranean fruiting give rise to an extended period of seed formation and to low reproductive efficiency. The percentage of pegs that bear pods ranges from 20% to 70% (Kowal and Kassam, 1978; Choudhari *et al*., 1985;

Chapman *et al*., 1993).

Borget (1992) reported that the mature seeds may represent only 10-20% of the flowers that are produced. According to Smartt (1976), the mature nuts are oblong and indehiscent pods each containing 1-5 seeds. He observed that single-seeded pods may be produced when all the ovules except the proximal abort. Borget (1992) found that the pod size may range up to 8.0cm x 2.7cm and the fruit consists of valves, structurally dehiscent but functionally indehiscent. He observed that time of maturity is affected by temperature and variety. Borget (1992) reported that the fruit (pod) takes about 60 days from the time of fertilization to full maturity. Work done by Lim and Hamdan (1984) depicted that the size of the mature pod is influenced by genotype, soil, method and time of cultivation.

2.4. Cultivars

On the basis of the variable growth habit, Kochhar (1986) and Williams *et al*. (1989) classified groundnut as erect or bunch types and runner or spreading types. They observed that the bunch types are short-season cultivars with an erect growth habit and mature 90-110 days after sowing while the runner types are mainly long-season cultivars requiring 120-180 days to maturity. Kochhar (1986) and Williams *et al*. (1989) found that the runner varieties yield better, in regions with longer wet seasons and are more adapted to the forest, derived savannah and the wetter Guinea savanna Zones of West Africa, while the bunch types predominate in the seasonally arid areas and are more suitable for machine harvesting.

Kochhar (1986) and Williams *et al*. (1989) observed that the varieties Spanish 207-3, MK 383, No. 146 and Mani Pintar were released in Ghana in 1960 for commercial production. They reported that the six varieties released in 1970 include Florispan Runner, Natal Common, Shitaochi, Tirik, Philippine Red, and Kumawu and most of these varieties perform well in their areas of adaptation with yield potential of 1,700 – 1900 kg ha^{-1} and maturity periods of 90 – 130 days. Asibuo *et al*. (2008) reported that the varieties currently grown in Ghana include Mani Pintar, Tirik, Florispan, Dagomba Hypogaea, F-Mix, Nkatepa, Sinkarzie, Kumawu early, Nkate kokoo, Baasare Fastigiata, Broni nkatee, Afu, Nkoranza local, Atebubu local, Aprewa, Kintampo local, Shitaochi, Broni, Kamaloo, Kofi Nsarko, Kowoka, Broni fufuo.

2.5. Composition, Nutritional Quality and Uses

Work done by Nwokolo (1996) showed that the shell represents about 25% of the dry weight of unshelled peanut, and the kernel comprises 75% and the cotyledons are the main storage tissues and are a concentrated source of protein, lipids, and dietary energy. He found that the amino acid profile of raw peanut is in many respects inferior to the profile of raw soybean and the protein content of raw peanut is only about 70% that of raw soybean. According to Nwokolo (1996), peanuts are low in Sulphur-based amino acids such as methionine, cysteine and cystine but they are a good source of lysine, tryptophan and threonine. He found that peanuts are a reasonable source of dietary minerals, especially potassium, phosphorus, and magnesium. However, Nwokolo (1996), found that peanuts are poor sources of fat soluble vitamins like A, D and K. He noted that peanut oil is an excellent source of mono- and polyunsaturated fatty acids, exceeding the levels of these fatty acids in soybean and corn oil, but significantly lower than in sunflower and safflower oil. Studies by the same author showed that peanut oil contains about 1 % palmitic acid and 80% oleic and linoleic acid. Worthington and Hammons (1971) and Woodroof (1983) found that eight fatty acids account for more than 98% of the total fatty acid composition of groundnut oil. According to Shibahara *et al*. (1977), palmitic, oleic and linoleic acids account for more than 80% of the total fatty acids after 30 days growth. Young and Waller (1972) and Sekhon *et al*. (1972) indicated that these acids contribute approximately 90% of total fatty acids at kernel maturity. Lusas (1979) and Woodroof (1983) reported that protein makes up 12.036.4% of the groundnut kernel and the percentage increases during ripening, with the seeds from older plants showing a higher capacity to accumulate protein than seeds from young plants. Work done by Rao *et al*. (1965); Oke (1967); Rahman (1982) and Woodroof (1983) showed that carbohydrates in groundnut kernels consist of water-soluble carbohydrates (monosaccharides, disaccharides) and oligosaccharides including starch, raffinose and starchyose. Studies by Rao *et al*. (1965), Oke (1967), Derise *et al*. (1974) and Woodroof (1983) showed that mature kernels are reported to contain 9.5-19.0% total available carbohydrate as both soluble and insoluble carbohydrate. Derise *et al*. (1974) and Woodroof (1983) found that crude fibre levels in groundnuts are reported to range from 1.2% to 5.0% and the fibre content decreases slightly with boiling or removal of skins, whereas roasting leads to a slight increase. Savage and Keenan (1994) noted that raw groundnuts are known to contain an excellent source of certain vitamins, especially E, K and B group. Smith (2002) reported that raw peanuts have some antinutritional factors like trypsin inhibitors, various lectins. Smith (2002) indicated that groundnuts have very low concentrations of most of the antinutritional factors found in raw soybean. He noted that goiterogenic factor has also been isolated and identified in the testa of the peanut.

2.6. Ecological Requirement

2.6.1. Climate: The groundnut plant grows under a wide range of climatic conditions and adapts to wide range of environments. It requires a lot of sunshine and high temperatures. Bolhuis and de Groot (1959) reported that groundnuts are grown between 40 ^{o}N and 40 ^{o}S of the equator in areas which are free of frost at least during the summer season. Bolhuis and de Groot (1959) observed that groundnuts thrive well in areas with a temperature range of 20-35^{o}C and speed of emergence increases with increasing temperature to 33 ^{o}C. According to de Beer (1963) and Cox (1979), seedling dry weight increments are highest at 27 – 28 ^{o}C, at least in controlled environments. Bagnall and King (1991) revealed that measurable growth ceases at about 11-14 ^{o}C. Choudhari *et* *al*. (1985) described differences between genotypes and seasons in crop development, patterns of LAI and leaf area duration. Williams *et al.* (1990) found that LAI (or fractional interception of radiation) explained 90% of variation in rhizobial nitrogen fixation.

Williams *et al.* (1990) indicated that maximum growth rate is broadly coincident with maximum LAI, and the time at which it is reached is accelerated by temperature.

Leong and Ong (1983); Bagnall and King (1991) found that time to first flower appearance does not depend much on day length and this occurs earliest at high temperature. Bunting and Elston (1980) cited times to maturity for cultivar Natal Common of 90, 105 and 120 days in Sudan, Tanzania and Transvaal, where mean temperatures during the growing season were 25, 22 and 19^{o}C, respectively. Bagnall and King (1991) observed that high radiation accelerates flowering. Cox (1979) noted that in contrast, maximum flowering and highest peg and pod numbers occur under short days and at moderate temperatures (24-27^{o}C). Bolhuis and de Groot (1959) reported cultivar differences in flowering response to temperature.

Choudhari *et al*. (1985) reported that the primary branches contribute the majority of pods (90%). Earlier work done by Duncan *et al*. (1978) showed that pod formation results in the channeling of between 40% and virtually 100% of current photosynthate into reproductive parts. In Florida, Duncan *et al*. (1978) observed that within a range of cultivars genotypic differences in pod growth rate and final yield were closely related to variation in the percentage of photosynthate partitioned to the pods. Likewise, increasing plant population causes a reduction in all yield components per plant, but number of pods and seed weight per pod were reduced more than individual pod weight. Defoliation experiments showed that once a pod has reached some critical size, it will continue to develop and reach maturity at the expense of photosynthate supply to younger pods which abort under stress.

The coincidence of a moderate (20-30 ^{o}C) temperature optimum for net photosynthesis, flower formation and pod growth, and the absence of day length sensitivity for the onset of flowering, results in groundnut yields being outside the hot tropics. Williams *et al*. (1975) reported kernel yields of 6, 5 and 3 t ha^{-1} at 1300, 900 and 1600 m elevation respectively at 18 ^{o}S latitude, where as 2-3 t ha^{-1} was a common maximum in lowland African Savanna (Kowal and Kassam, 1978) and lowland India and Indonesia. Weiss (2000) found temperatures between 25 and 30^{o}C to be optimum for plant development. Weiss (2000) again, observed that optimum annual rainfall for groundnut cultivation ranges from 800 – 1300 mm per year, but it could tolerate rainfall as low as 200 mm per year. Virmani and Singh (1986) noted earlier that water was the major constraint to yield in groundnut - growing areas. They observed that once established, peanut was drought resistant, and to some extent tolerated flooding. According to Weiss (2000), once pods are mature, rainfall will adversely affect the crop as some cultivars have a very brief dormancy and germinate under suitable conditions. Even though climatic and agronomic factors are beyond the control of the farmer, they can be manipulated to some extent to support plant life.

Ike (1986) indicated that in controlled environments drought reduces root length and pod numbers. By contrast, in sandy soil in the field, moderate water deficits do not necessarily affect root growth (Robertson *et al*. 1980) or yield (Wright, 1989). Ike (1986) found presumably the lack of sensitivity to drought in the field is due to exploitation of subsoil moisture. Chapman *et al*. (1993) showed that water deficits may halve crop photosynthetic efficiency (E) from 1.12 to 0.63g MJ^{-1} at 49 -70 days after sowing. They further found that drought in the early reproductive stage reduces flowering and peg initiation. Chapman *et al*. (1993) again reported that flowering and peg growth may begin again after re-watering. Raw Materials Research and Development Council (RMRDC, 2004) found dry weather to be important for ripening and harvesting. According to Lee *et al.* (1972), groundnut is a day neutral plant and thus little affected by day length. However, they found that plant growth is adversely affected by low light intensity and bunchy types are generally more severely affected by climatic variation than runner types. The crop appears to be adapted to high relative humidity (Lee *et al.* 1972) and has relatively poor water use efficiency (1.8 kg dry weight per tonne of water used throughout the growing season; Pallas and Stansell, 1978). According to Chapman *et al*. (1993), yields often reflect the pattern of soil water availability, and there are numerous reported yield responses to irrigation. Yield responses such as these are the cumulative effect of water deficit on flowering and peg formation and pod development. Chapman *et al*. (1993) observed that drought during pod-filling caused abortion up to 45% loss of yield through the death of the youngest pods.

2.6.2. Soil and Nutrients

Groundnuts grow best in well-drained soils of a loose to friable consistence. Texturally, many important groundnut soils are sandy and occur within the orders Alfisols, Entisols, Inceptisols and Ultisols.

Light-textured soils allow ease of sowing and establishment although Arndt (1965) showed that the relatively large stem diameter of the groundnut seedling ensured emergence from most surface crusts. However, the soil below the surface should be loose and porous as even small reductions in porosity can severely affect growth. Nicou and Chopart (1979) observed a decrease in soil porosity in the cultivated layer from 44% to 38% reduced root yields in the 10-20cm horizon from 1000 to 100 kg ha^{-1}. More importantly, loose and friable soils allow peg penetration and development and ease of lifting at harvest. Underwood *et al*. (1971) found that though pegs were capable of exerting great force, a surface crust of 1.5 cm could adversely affect penetration and pod development.

Heavy clay soils make harvesting difficult as yields are reduced through peg fracture and pods may be stained by adhering clay (MoFA, 2007). Work done by Hack (1970) showed that lighttextured soils are also less liable to waterlogging, to which the groundnut seedling is sensitive after periods as short as 24 h. Reid and Cox (1973) observed that waterlogging affects the growth of rhizobia of young plants when nitrogen is in high demand. Reid and Cox (1973) found that some groundnuts are grown successfully on heavier soils though usually on raised beds.

Groundnut tolerates both acidic and alkaline soils but pH of 6 – 7 is best for production. Groundnuts are particularly sensitive to low levels of available calcium even though they are tolerant of aluminium (Adams and Pearson, 1970) and manganese (Nicholaides and Cox, 1970).

Wolt and Adams (1979) indicated that calcium deficiency is revealed by „Pops" (pods containing aborted or shriveled kernels). They also noted that low calcium levels are associated with increased vegetative growth that remained green later in the season, with greater, but infertile flower production and with reduced kernel-yield.

Wolt and Adams (1979) showed that calcium for normal pod and kernel development was very dependent on direct uptake by the pod from the soil. Wright (1989) observed that groundnuts growing in dry surface soil but with roots in moist subsoil exhibited poor pod development and kernel abortion. This mode of calcium uptake and distribution explained why there was no response to currently applied lime if it was not incorporated in the pegging zone (7 – 9 cm), Hartzog and Adams (1973) and why drought may induce calcium deficiency (Rajendrudu and Williams, 1987).

Of the bunch types, small seeded Spanish types are less responsive to liming and have fewer „pops" than the large-seeded Virginia Bunch types (Hobman, 1985). This is consistent with observation by Boote *et al.* (1982) that large-seeded varieties have a lower surface to volume ratio than small-seeded varieties. Kvien *et al.* (1988) observed that other pod characteristics also influence calcium movement to the seed. They found that thin, light hulls and long pod maturation allow calcium absorbed in the pod walls to move on into the seed.

Chesney (1975) reported that high potassium fertilization can antagonize calcium uptake, leading to a higher requirement for calcium. He found that the response to nitrogen fertilizer was often small and erratic, even on nitrogen-deficient soils. Williams (1979) noted that at very high yield levels the nitrogen requirement of nodulated groundnuts can not be wholly met from symbiotic nitrogen. In Ghana, Ofori (1975) reported no response but earlier work had responses of up to 15 kg nitrogen ha^{-1}, which were higher when there had previously been a grass fallow. Acuna and Sanchez (1969) found no response to nitrogen in Venezuela, but in Brazil de Tella *et al*. (1970) obtained yield responses in three out of five experiments. de Tella *et al*. (1970) found that sandy soils are liable to be low in phosphorus, but as phosphate fixation and crop removal on such soils are generally low, only low rates of phosphorus application are required. Bell *et al*. (1989) observed that higher rates of fixation Oxisols and oxidic Ultisols require higher rates of phosphorus application. They found that mycorrhizal fungi could improve the uptake of phosphorus and other elements, example zinc, even at high levels of applied phosphorus. According to ICRISAT (1986), mycorrhizal colonization of the roots varied, being 20-50% for Spanish, 17 - 31% for Valencia, 22 - 50% for Virginia bunch, and 21 – 36% for runner types in India. Singh and Abrol (1985) found groundnut to be susceptible to excess exchangeable sodium found in sodic soils.

2.7. Planting

Seeds are used for commercial propagation, although stem cuttings could also be used for research work. Shelled seeds are preferred for planting as unshelled nuts tend to encourage rotting of the seeds in the pods or may contain weevilled and diseased nuts which can not be seen and removed before planting. Germination takes place 5-7 days after planting. Larger seeds are even more sensitive to moisture stress. The nuts are traditionally planted by hand, 2-3 seeds per hole, although cotton or maize planters may be suitably adjusted to plant groundnuts by equipping them with groundnut plates. Only healthy and sound seeds are used for planting. Work done by Paulraj and Ignacimuthu (2006) showed that fungicide / insecticide seed dressing such as Fernasan D or with Apron plus or Apron star at 1 satchet/5 kg of seeds will, therefore, ensure a full stand of the crop after germination, and will prevent pests such as squirrels, mice, rats, lizards, termites and birds from destroying or removing the seeds from the soil after sowing. They established that inoculation of the seeds with the proper culture of *Rhizobium* bacterium was often a wise insurance policy and recommended virgin soils or in areas where groundnuts, cowpeas, soyabeans, limebeans or centrosema have not been grown before. They recommended that inoculation could be replaced by heavy nitrogen application but this was not economically feasible and its effect was often temporary, while inoculation enabled the plants to enhance the soils nitrogen resources during their growing period.

MoFA (2007) recommended a spacing of 30 x 30 cm and 30 x 45 cm on flat or raised beds for bunch types. It indicated that in commercial plantings the aim should be to adopt the spatial arrangement that will give at least 120,000 plants per hectare. According to MoFA (2007), wider spacing should be used for the local varieties which are mainly runners. A planting distance of

30 cm between holes on ridges and 60 - 120 cm between ridges had been recommended in Ghana for Mani pintar and other semi-erect varieties under Northern Ghana conditions. One to three seeds per hole should be enough if sound and dressed seeds were used for sowing.

Generally, 90 cm x 20 cm for spreading and 60 x 10 cm for bunch types had been recommended (MoFA, 2007).

Time of planting depends on the variety as well as the location. Sowing should be timed in such a way as to match the plant‟s cycle as closely as possible to the probable distribution of rainfall and other important climatic factors, RMRDC (2004). Work done by MoFA (2007) showed that in southern and mid-Ghana, including Ashanti and Brong Ahafo regions, sowing starts in MarchApril during the major season, and September - October in the minor season. In the Northern and Upper Regions, sowing starts in May - June. Sowing early during the planting season generally gives higher yields and quite effectively controls rosette disease. Irrigated groundnuts are sown around October/November (Paulraj, and Ignacimuthu, 2006; Youdeowei, 2002).

2.8. Fertilizer Application

Dokli (2007) found that groundnuts responded to phosphatic fertilizers because phosphorus influenced the rate of nitrogen fixation. Work done by Paulraj and Ignacimuthu (2006) and Youdeowei (2002) revealed that single (50-100 kg/ha) superphosphate has been depicted to give better results than other forms of phosphatic fertilizers because of the high content of calcium and sulphur both of which are important in groundnut nutrition. Paulraj and Ignacimuthu (2006) and Youdeowei (2002) noted that on poor soils, a light dressing of nitrogenous fertilizer (50 kg/ha of sulphate of ammonia corresponding to about 10 kg/ha N) will give the emerging seedlings a good start before they develop extensive and ramifying root system for nodulation. They observed that weakly developed plants are not able to produce well developed nodules and thus do not produce sufficient amounts of nitrogen. Further, the Raw Materials Research and Development Council (RMRDC, 2004) recommended the application of 54kg per hectare of P_2O_5 and 25kg per hectare of K_2O in all groundnut-producing areas. The Institute exhibited that phosphorus nutrient (P_2O_5) should be applied in the form of superphosphate (SUPA) and this will require 300 kg or 6 bags of the 50 kg weight size per ha. The Institute also noted that the application of 60 kgN, 55-kgP_2O_5 ad 30 kgK_2O/ha to groundnut/sorghum and 90:60:30 kgN, P_2O_5 and K_2O/ha respectively to groundnut/maize intercrops is yield-promising. Even though potassium was necessary to guarantee healthy development of the groundnut plant and good yields, it must always be applied with caution (RMRDC, 2004).

Chesney (1975) reported that the groundnut plant was deep-rooted and quite drought – resistant, being able to exploit nutrients and moisture in the lower levels of the soil. Therefore, in the high rainfall areas, one of the best ways of fertilizing groundnuts was to put enough fertilizer on the preceding crop so that some will be left in the soil for use by the groundnut plants. In the drier areas, however, it was probably more practical in many cases to apply the fertilizer to the groundnut crop.

2.9. Weed Control

Sandler (2007) observed that the main priority after emergence was to keep the crop weed-free and that young groundnut was highly sensitive to competition from weeds, and yields declined sharply. He estimated weeds could reduce yield by 18-70% and noted that weeding should be carried out when the weeds were tender at about 2-3 weeks after planting. Sandler (2007) recommended repeated weeding but weeding close to the plant should stop when pegs start to form. Further, he showed that mechanical weed control methods varied from simple hand pulling to the use of hand-hoe, animal and tractor drawn cultivators. Iven (1976) also revealed that weed control was very essential in groundnut cultivation, especially during the first five weeks after emergence. He indicated that ideally there should be no weeding after flowering and the beginning of pegging and a maximum of three weedings or hoeings, done two weeks, four weeks and seven weeks after planting was recommended. Hay (1974) made the following observations. In mechanized agriculture, one or two early cultivations using a suitable inter-row cultivator, a rotary hoe or a flexible shank weeder were recommended. Again, a third shallow cultivation with an inter-row cultivator was helpful before harvesting. In some areas, appropriate pre-planting or pre-emergence herbicides may be applicable. For pre-emergence weedicides such as Gesatop, a semizine-base herbicide, have been used to control both broad-leaved weeds and grasses in groundnut. They may be applied during planting or any time before the seedlings emerge. According to Sandler (2007), basogram (active ingredient: bentazone) may be used for post emergence from the first trifoliate leaf onwards at the rate of 1.5 litres/ha in a suitable volume of water. Hand pulling and earthing up should be done at this stage.

2.10. Rotation

Rotation of groundnut plants with crops such as millet, sorghum, maize, cotton, tobacco etc is highly recommended to minimize the incidence of mosaic or rosette and leaf spot diseases. For example, at Katherine, North Australia, sorghum grain and stover yields were respectively 77% and 56% higher after groundnuts than after sorghum and grain nitrogen yield was almost double (Phillips and Norman, 1962). Lombin (1981) found that in North Nigeria, the average yield over 6 years of sorghum immediately following sorghum, cotton or groundnuts was respectively 2037, 2553 and 2861 kg ha^{-1} and the average yield of maize after 7 years continuous sorghum, cotton or groundnuts was respectively 2503, 3568 and 4478 kg ha^{-1}. In a six - year study in which maize succeeded various crops, maize after groundnuts gave the highest yield of 1.77 tons/ha, while maize yields after the other crops ranged from 0.75 - 1.0 tons/ha. When no fertilizers were applied, maize yield in Guinea savanna zone was nearly 90% higher when grown after groundnuts than when grown after maize. Lombin (1981) reported that about 60 kg/ha N was saved by preceding maize with groundnuts rather than continuous maize cultivation. He further reported that groundnuts were restorative of topsoil nitrogen.

2.11. Intercroppping

Groundnuts are cultivated both as a sole crop and a component of intercrop mixtures. In the Northern Guinea Savanna Zone of West Africa, about 70% of the crop is grown in mixtures with two or four crops, including pearl millet, sorghum and cowpea (Kowal and Kassam, 1978), though in Senegal a higher proportion of sole crop was found. Okigbo and Greenland (1976) reported the proportion of groundnuts in mixed crops in Nigeria and Uganda as 96% and 78% respectively of the total area sown to the crop in each country. Whereas in short-season wet- and - dry climates groundnuts sown in mixtures with other short-season crops as indicated above, in more extended rainfall regimes they are sown with both short - and long - season crops. For example, in the South Cameroon, groundnuts are a component in intercrop mixture with shortseason maize and long-season tubers and plantains (Mutsaers, 1978). Gibbons *et al. (*1972) found that in India, groundnuts may be inter-planted with pigeonpea and with cotton. Work done by Dokli (2007) showed that groundnut-maize intercropping yielded 0.46 t ha^{-1} of groundnut seeds and 1.38 t ha^{-1} of maize seeds. According to Norman (1972), the presence of groundnuts appears to confer only a small yield advantage over the yield of sole crops when the duration of growth of the crops is similar as in groundnut and pearl millet intercrop, while intercropping gives a large yield increase when growth duration differs by up to three months as in the groundnut / pigeonpea intercrop.

2.12. Diseases and Insect Pests

Work done by Paulraj and Ignacimuthu (2006) depicted that diseases of groundnuts in West Africa may be viral and fungal diseases although bacterial wilt and nematode infestation are of significance in some countries. Kokalis-Burelle *et al*. (1997) and RMRDC (2004) cited some groundnut diseases to include groundnut rosette disease, leaf spot (early and late leaf Spot), stem rot, seed rots, pre-emergence rots, mycotoxin infection, leaf rust, pod rot, southern blight, seedling diseases, peanut rust and tikka.

Melouk and Shokes (1995) and Youdeowei (2002) recommended methods of control of these diseases to include the use of resistant cultivars, deep ploughing to move plant debris away from the soil surface, crop rotation to avoid build up of the disease in the soil, early planting, removal of any volunteer plants and weeds which serve as alternate hosts, improved drainage to minimize the spread of diseases in the soil, removal and burning of affected plants and seed dressing with appropriate fungicides.

Peanut is attacked by a wide variety of insect and mite pests. According to Paulraj and Ignacimuthu (2006), the main insects that attack peanuts are the leaf feeding caterpillar, thrips, stalk borers, leaf eating ants, bean and flea beetles, aphids and leaf miner.

2.13. Maturity and Yield

Work done by RMRDC (2004) revealed that the maturity period of groundnut depends on variety and may vary from 90 days for early-maturing varieties to 150 days for late-maturing varieties. Under favourable conditions, yield of unshelled nuts up to 5 tonnes per hectare is obtainable. RMRDC (2004) found that yield depends on the kind of variety used and agronomic practices employed. MoFA (2007) reported that yields of groundnut are one tonne per hectare but the new varieties are 2.3 to 2.9 tonnes per hectare.

2.14. Effects of weeds on crop growth and yield

Akobundu (1987) defined weeds as plants growing where they are not wanted, plants out of place or plants whose usefulness has not been discovered. However, Akobundu (1987) observed that every plant on this earth is useful for human beings, crops and animals and hence weeds can be considered as useful plants such as medicinal weeds. For instance, weeds provide food for birds, rodents and their predators. Many studies have also clearly revealed that stimulatory allelopathic effects of weeds on crops can be utilized successfully for higher crop production (Oudhia, 2003). Iven (1976) reported that plants are also considered weeds when they interfere with the utilization of land and water resources or otherwise intrude upon people"s welfare. He confirmed that some plants are weeds because they are toxic to mankind and/ or livestock, or are generally obnoxious. Iven (1976) again, found that traditionally, however, there are certain plant species that are thought of as weeds and there are others which do not fit this classification. For example, a bean plant growing in a groundnut field is technically a weed if it was not planted there, but it is not traditionally thought of as a weed. Work done by Akinsanmi (1975) revealed that weeds grow in the fields where they compete with crops for water, soil nutrients, light and space and also harbour insect pests and micro-organisms and thus reduce crop yields. Certain weeds release into the soil the inhibitors or poisonous substances which are harmful to the plants, human beings and livestocks (Oudhia, 2007). Akobundu (1987) indicated in his work that weeds increase the expenditure on labour and equipment, render harvesting difficult, and reduce the quality and marketability of agricultural produce. According to Iven (1976), weeds block the drainage and impede the flow of water in canals and water-transport channels and their growth in the rivers renders navigation very difficult. Oudhia (2003) observed that the dense growth of weeds in water pollutes the water because they deoxygenate the water and kill the fish.

2.14.1. Characteristics of weeds

Muzik (1970) and Zimdahl (1980) reported that weed seeds germinate earlier; their seedlings grow faster; flower earlier; form seeds in profusion; and mature ahead of the crop they infest. They also noted that nature has bestowed these qualities on weeds so that their seeds are collected unwarily along with the produce of the crop at harvest and get distributed to other places where the produce may be taken. Zimdahl (1980) again, found that weeds have the remarkable capacity to germinate under varied conditions, but very characteristically they are season-bound and the peak period of germination always takes place in certain seasons in regular succession year after year. He observed another characteristic of weed seeds as the possession of dormancy which is an intrinsic physiological power of the seed to resist germination even under favourable conditions. Anderson (1977) observed that weed seeds do not lose their viability for years even under adverse conditions. Sultan *et. al.* (1994) and Oudhia (2003) reported that weeds have high rate of fecundity, efficient seed dispersal mechanisms and adverse allelopathic effects on many species and this enables their quick spread and establishment.

2.14.2. Classification of weeds

Work done by Iven (1976) showed that weeds belong to the class Angiospermae (flowering plants) which have two subclasses: Monocotyledoneae (monocots) and Dicotyledoneae (dicots). Iven (1976) indicated that weeds can be classified on the basis of their life forms, life span or history or cycle, growth habit, habitat and botany. He noted that on the basis of life forms, weeds could be classified as narrow-leaf (grasses and sedges) weeds and broad-leaf weeds. Sandler (2007) reported that examples of grass weeds included *Brachiaria deflexa, Brachiaria lata, Digitaria horizontalis, Rottboellia cochinchinensis, Paspalum orbiculare, Panicum maximum* etc while sedges include nut grass or *Cyperus* spp. (*Cyperus rotundus*, *Cyperus distans*, *Cyperus difformis*), *Kyllinga* spp. and *Mariscus* spp. King (1966) also revealed that broad-leaf weeds are usually dicots and their leaves have net or reticulate venation and they include *Ageratum conyzoides*, *Acanthospermum hispidum*, *Chromolaena odorata*, *Euphorbia heterophylla,* and *Commelina* spp. Sultan *et al*. (1994) observed that annual weeds live and produce their seeds in a single growing season while biennial weeds need two growing seasons; in one season they pass through their vegetative or rosette stage, followed by reproductive stage in the next season. They found that the multiplication of both the annuals and the biennials was through seed whereas perennial weeds live indefinitely and are propagated not only through seeds but often vegetatively through underground structures, such as rhizomes, stolons, bulbs and tubers. They also reported that perennial weeds are of two types: the simple and the creeping. The former multiply only through seeds and have no normal means of spreading vegetatively. However, if they are injured or cut, the severed portion produces new plants. Creeping perennials are spread by creeping roots, creeping above-ground stems (stolons), and creeping underground stems (rhizomes).

Work done by Sultan *et al*. (1994) depicted that aquatic weeds (hydrophytes or water inhabitants) are classified into three types, namely, submerged, emerged and floating. They noted again that submerged aquatics are anchored to the bottom of the habitats, example, a ditch, and grow entirely beneath the surface of the water and emerged aquatic weeds have their roots beneath the surface of the water, but the leaves and stems are above the water-line. Floating weeds or surfaced aquatics either float freely on the water or float only in a limited area. Furthermore, work done by Muzik (1970) showed that weeds can either be total parasitic or partial parasitic which parasitize certain host plants, which they directly attack and deprive them of water, nutrients and assimilates.

2.14.3. Weed-crop competition

Competition was defined by Aldrich (1984), as the relationship between two or more plants in which the supply of growth factors falls below their combined demands. Zimdahl (1980) observed that weeds compete with crops directly for these growth factors-water, nutrients, light, oxygen and carbon dioxide- and these interfere with the ability of the crop to utilize these resources, thus hampering proper crop growth and development, resulting in significant reduction in yields, biological nitrogen fixation and quality of produce. He added that all crops irrespective of their patterns are susceptible to early weed competition and the adverse influence of weeds on crop is most pronounced when growth factors are limited in supply.

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 onemetre 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.

Sweet and Minotti (1980) observed that moisture is implicated early in weed-crop competition before other growth factors become limiting. However, the precise time and duration of the period of maximum competition depend on factors such as the relative growth rate of the crop and weeds, crop and weed densities, time of planting, type of crop (variety), tolerance to moisture and nutrient stress and cultural practices (Kasasian *et al*., 1969). Work done by Oudhia (2003); Sandler (2007) and Akinsanmi (1975) showed that weeds are plants whose growth interferes with that of the crops for which the soil is meant and, therefore, become a nuisance to man.

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. The ability of the weeds to compete with cultivated crops depends on their root system, height, leaf area, density and frequency of occurrence.

Some weeds even utilize cultivated crops for support and strangle them to death. This competition adversely affects growth and development of crops. According to Lavabre *et al*. (1991), yield of maize may typically be reduced by one tonne per hectare due to weed competition. This may be 10-15% of a good crop but may be one-third of a poor crop. Losses caused by uncontrolled weed growth in selected crops in Africa put yield reduction in maize for

Ghana at 55%, Kenya 34% and Nigeria 40% (Akobundu, 1987). In rice the losses were 84% for Ghana, 63% for Liberia, 90% for Nigeria and 48% for Senegal. In cowpea, it was 67% for Ghana, 60% for Nigeria (Akobundu, 1987). RMRDC (2004) also found that weeds are estimated to reduce groundnut yield by 18-70%.

Apart from reducing yields, weeds also affect crop quality by contamination of the harvested produce (Akobundu, 1987). The presence of weed seeds such as those of *Rottboellia cochinensis* in maize or rice and *Sclerocarpus africanus* or *Solanum nigrum* in cowpea reduce the quality and market value of these crops. Sandler (2007) stated that the separation of the weed seeds from the crop seeds becomes extremely difficult when the seeds are of the same colour and size. The cost of separating these weed seeds from crop seeds adds to cost of production of the crop. Also, the presence of weeds can also reduce the quality of forages or make them unpalatable or even poisonous to livestock (Akobundu, 1987).

2.14.4. Critical period for weed control

Anil (1998) observed that to prevent yield loss it may not be necessary to control weeds for the entire crop-growing season. He further said that there is a certain window during the crop"s life cycle when it is most susceptible to competition from weeds. This "critical period for weed control" is defined as the time-interval during which weeds must be controlled to prevent unacceptable yield losses. Anil (1998) noted that weed control outside this window may not be necessary than to prevent possible interference in harvest operations and or weed seed production. The removal of weeds from the growing crops facilitates easy harvesting and gives a high-quality produce without admixture with weed seeds (Sandler, 2007 and Anil, 1998).

2.14.5. Methods of weed control

Work done by Holm *et al*. (1977) and Sandler (2007) indicated that nature has provided weeds with a number of devices that help them to be disseminated widely. They further observed that the agencies that facilitate the dispersal of weed seeds far and wide are water, wind and animals, including man. Their report also revealed the troubles that weeds create in crops, soil and water which summed up in the adage "one year of seedling is seven years of weeding". To avoid such a situation, a wise step is to follow the principle "prevention is better than cure". As weed seeds are so readily dispersed by natural agencies and by the farmer himself, it is important to prevent weeds, whether in crops, on borders or bunds, in fences or in irrigation-channels, from flowering to setting seed. Preventive methods consist of sowing crop seeds not contaminated with weed seeds, using manure and irrigation water not laden with them and the enforcement of weed control laws and seed-certification measures (Iven, 1976; Sandler, 2007; Akobundu, 1987).

In the olden days, early weed competition was minimized by the slash-and-burn and hand weeding methods. This system has been destabilized in recent times as a result of increasing human populations on limited land, decreasing fallow periods, declining soil fertility and increasing weed problem (Akobundu, 1980).

Sandler (2007) established that the primary goal of weed control or management is to maintain an environment that is detrimental to weeds as possible through the successful employment of specific or combined methods. These methods are mechanical or physical, cultural, biological, chemical and integrated.

2.14.5.1. Mechanical weed control

Hay (1974) indicated that mechanical weeding includes all weed control practices where a mechanical device is used for weed control with animals or fossil fuel as the source of energy. He also depicted that mechanical weed control was introduced into agriculture by using animaldrawn equipment and mechanically powered implements early in the twentieth century. Both animals and tractors are used with varying degrees of success in the tropics. Stout *et al*., (1973) indicated that the purpose of mechanization is to make humans more efficient users of power. Hand-pulling or hand-weeding, hoeing, tilling, mowing, burning, flooding, smothering, etc. are examples of physical methods of weed control, involving the use of physical energy through implements, manual, bullock-drawn or power-operated. Stout *et al*. (1973) found that mowing just above groundnut top growth may also reduce weed competition and enhance establishment. Work done by Muzik (1970) and Iven (1976) showed that hand-weeding is the most efficient method, but it is back-breaking, time-consuming and costly. They also found that with the gradual global industrialization, coupled with the raising standards of living and literacy, manual labour is becoming scarce. Further, their report indicated that the high wages paid to the hired labour reduce the profits of the farmer.

2.14.5.2. Cultural weed control

Iven (1976) observed that weeds under many conditions are better competitors than crop plants for light, water, nutrients and space. However, he further noted that farming practices are capable of changing the condition in such a way as to enable the crop plants to compete with weeds successfully or to reduce their interference to the minimum and thus preventing them from acting as impediments to increased crop production. Seeds with good germination will give the crop a vigorous and close stand and thus enable it to outcompete the weeds. Lavabre *et al*. (1991) stated that cultural control includes any husbandry or management practices that enhance the crop‟s abilities to compete with weeds or to minimize weed interference and consists of hand weeding, mulching, burning, flooding, maintenance of soil fertility, proper spacing, time of planting, optimum rate and placement of fertilizer, multiple cropping and crop rotation. Among these methods, hand weeding which consists of hand pulling, hand slashing and hoeing of weeds is the most popular because it is a single process and because farm sizes are small. Collectively, these manual weed control methods represent varying practices in which human energy is directly utilized to remove weeds growing in undesirable locations. Muzik (1970) observed that manual weeding has limited agricultural productivity because there is a limit to the amount of land area that can be weeded manually, even when labour is free. He added that the total energy used in hand weeding is far less than where chemicals and machines are used.

2.14.5.3. Chemical weed control

Craft (1975) described chemical weed control as the use of chemicals called herbicides or weedicides to control weeds. He reported that the control of weeds in the growing crops with weedicides increased their yields and ensured the efficient use of irrigation, fertilizers and plantprotection measures, such as the spraying of insecticides and fungicides. Chemical weed control can be adopted quite in time and in situations and under conditions which make manual or mechanical weeding difficult. Craft (1975) observed that a great advantage of chemical method lies in killing weeds in the crop row or in the immediate vicinity of crop plants. He found that chemical method is easier, less time-consuming and less costly than weeding by hired labourers. A study by Craft (1975) showed that the broad-spectrum tolerance of rhizome groundnut to herbicide has facilitated preparation of a weed control programme incorporating the use of preemergence applications of benefin, trifluralin or vernolate, post-emergence applications of alachlor and dinoseb, and routine applications of bentazon and 2, 4-D for broadleaf weed control, and sethoxydim and fluazifopbutyl for grass control as required. Sethoxydim, but not dalapon, can be used to kill bermudagrass (*Cynodon dactylon*) rhizomes contaminating groundnut rhizome planting material, thus improving initial performance significantly (Sandler, 2007).

2.14.5.4. Biological weed control

In biological weed control, a "natural enemy" of the weed plants is used. Groups of bio-control agents for weed control include insects and mites; fungi and bacteria; herbivorous fishes; mammals like cattle, sheep, goat, buffalo for grazing and birds like ducks and geese as well as other plants (Craft, 1975).

2.14.5.5. Integrated weed control

Sandler (2007) stated that an integrated weed-control involves the utilization of a combination of physical, chemical and cropping or biological methods of weed control in a well-planned sequence so designed as not to affect the ecosystem. Craft (1975) noted that the nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation, the standard of crop husbandry, and the ready and timely availability of any method and the economics of the different weed-control methods are some of the potential considerations that determine the successful exploitation of the integrated weed-control approach.

2.15. Effects of plant spacing on crop growth and yield

According to Smartt (1976), crop yield response to spacing or plant population density usually follows either asymptotic pattern where yield rises to a maximum with increase in density or narrow spacing and then remain constant at high densities or a parabolic pattern where yield rises to a maximum but declines at narrow spacing or high densities. He further said that plant population, spacing and crop yield for most crops and total dry matter yield often conform to an asymptotic relationship while grain and seed yields conform to a parabolic relationship. Smartt (1976) found that a population of at least 100,000 plants per hectare is generally recommended for groundnuts. Many workers including Mozingo and Steele (1989) have shown the benefit of increased plant populations, but results have been variable and clearly depended on other factors. Kvien and Bergmark (1987) identified some of the important parameters involved. They showed that, at 30,000 plants per hectare, population density was the key limiting factor and yield improvements of nearly 30% could be achieved by increasing the population eightfold. They added that plants at high density tended to increase stem growth at the expense of assimilate partitioning to reproductive tissue. At high populations, yield was sensitive to planting date. A delay in planting by five weeks reduced yield by as much as 27%. At low densities plants were better able to compensate for late sowing. According to Kvien and Bergmark (1987), water stress reduced yield in all cases, despite the fact that plants showed some compensation for the stress by increasing harvest index.

A key problem with the groundnut crop is the range of pod maturities encountered at harvest. This in turn may be reflected in changes in seed size distribution. In general, as plant population density increases, number of seeds in the larger size grades tends to increase. The reason for this is that high interplant competition at high densities tends to suppress the development of later reproductive growth and, typically, earlier flowers are more successful at setting seed (Kvien and Bergmark, 1987). Sung and Chen (1990) have shown that, while cotyledon cell numbers are relatively constant, cell expansion rates tend to be much faster in early formed pods.

Nevertheless studies of Kvien and Bergmark (1987) showed that between 64% and 69% of pods failed to reach maturity in early sowings at high density, irrespective of field location. Very immature pods will not be picked up during machine harvesting, while slightly more advanced ones will contribute small seed to the harvest.

According to Kathirvelan and Kalaiselvan (2007), plant densities had significant influence on leaf area index of groundnut with the closer spacing of 30 x 10 cm producing the greatest leaf area index. Their work also indicated that plant population had a significant influence on the growth parameters of groundnut. For instance, they exhibited that plant height and number of branches per plant increased under wider spacing of 45 x 15 cm as compared to the closer spacing. They explained that as the feeding zone per plant under wider spacing was more when compared to closer spacing, the plants grew laterally and resulted in higher number of branches per plant. Furthermore, they noted that though higher number of branches per plant was more under wider spacing, it failed to produce higher leaf area index (LAI) due to less number of plant population per unit area and it reflected in lower values.

Kathirvelan and Kalaiselvan (2007) indicated that the total number of pegs per plant was significantly higher with a spacing of 45 x 15 cm. However, it was at par with 45 x 10 cm spacing. It was found by Kathirvelan and Kalaiselvan (2007) that plant geometry had significantly improved the fertility coefficient. The highest fertility co-efficient was observed with spacing of 45 x 15 cm, though it was at par with 45 x 10 cm. Kathirvelan and Kalaiselvan (2007) further reported that with regard to plant densities, wider spacing of 45 x 15 cm registered higher pegging per cent as compared to closer spacing, though it was at par with 45 x 10 cm spacing during both seasons. Kathirvelan and Kalaiselvan (2007) showed that pod setting per cent was more with the wider spacing of 45 x 15 cm and it was 10.03 and 4.59 per cent higher over the closer spacing of 30 x 10 cm. The number of matured pods per plant was highest with the widest spacing. Kathirvelan and Kalaiselvan (2007) generally reported that yield attributes such as fertility co-efficient, total pegs per plant, pegging per cent, pod setting per cent and partitioning efficiency were more with wider spacing of 45 x 15cm and 45 x 10 cm as compared to closer spacing. They explained that the better yield attributing characters in wider row spacing (45 x 15 cm) was mainly due to sufficient space between rows which encouraged the production of more vigorous plants and also lesser interplant competition for space, light, nutrient and moisture which resulted in more partitioning efficiency. The reduction in other yield attributing characters like pod, seed and haulm yields in wider row spacing was associated with lower plant population per unit area. Plant geometry did not alter the shelling percentage significantly during both seasons. N, P and K uptake were higher with closer spacing of 30 x 10cm while the lowest N uptake was observed under wider spacing of 45 x 15 cm. Kathirvelan and Kalaiselvan (2007) stated that this might be due to the enhanced total dry matter production (TDMP) since NPK uptake is computed by multiplying TDMP with nutrient content. Kathirvelan and Kalaiselvan (2007) and many other workers reported positive relationship between DMP and nutrient uptake in groundnut.

2.15.1. Spacing and other factors for plant growth

Environmental resources and the community plants sustain the growth of plants. Plant interaction in community reflects their demand on these environmental resources. Within a population, each plant is affected by other individuals within the population. Plants compete when supply of factors necessary for growth falls below their combined demand (Agasimani *et al*., 1984, Kalra *et al*., 1984 and Subrahmaniyan *et al*., 2000). Agasimani *et al*. (1984) indicated that competition may be either interplant or intraplant or both. Competition rises from the influence of one plant upon the surrounding physical factors and the effects of these modify factors upon its competitors.

Agasimani *et al*. (1984) indicated that the greater seed weight and number of seeds per inflorescence at intermediate densities were due to the timing of interplant (between plants) and intraplant (within a plant) competition. At the widest spacing (lowest plant density), both types of competition were absent during early stages of growth. According to Kochhar (1986), as growth proceeded, there was little interplant and even less intraplant competition until after flowering and seed setting. The large load of inflorescences leads to competition for assimilates among inflorescences and seeds on the same plant, that is, intraplant competition. This loss of efficiency at the widest spacing reflects greater intraplant competition, resulting in fewer seeds per inflorescence and reduced seed size compared to denser stands. Thus intraplant competition may be intense at low densities (Ramesh, and Sabale, 2001).

Agasimani *et al*. (1984) observed that in moderately dense stands interplant competition apparently becomes operative at the time of flower initiation or formation. The number of floral primordia laid down by each plant is considerably reduced. This reduced load laid more closely within the capacity of the plant as interplant competition intensified. According to Kalra *et al*. (1984), seeds per inflorescence and seeds per unit area achieved maximum values.

Under unfavourable environments, narrowing the rows of most crop plants will not increase yield. Taylor (1980) tested the hypothesis that during years of lower water supply soybean grown in wide rows would yield as much as or more than soyabean grown in narrow rows. Taylor (1980) observed that in a season of high water supply, seed yield in narrow (25cm) rows yielded 17% more than in 100cm rows. In two years of lower seasonal water supply, Taylor (1980) observed no difference in seed yield among 25, 50 and 100cm row spacings. Agasimani *et al*. (1984) stated that in dry years, severe water deficits occurred in the narrow row first, resulting in plants smaller in both height and leaf area index.

Sathyamoorthi1 *et al*. (2007), after a three-year study, suggested that closer spacing of 30 x 10 cm significantly had the highest dry matter production while wider spacing of 45 x 15 cm had the least dry matter production. They further explained that the lesser dry matter production recorded under wider spacing might be due to less plant population. They also reported that the total number of pods per plant varied significantly between plant densities. According to them, wider spacing (45 x 10 cm) had the highest number of pods per plant during the years. The wider spacing recorded the highest pod weight per plant in all the three years. The higher pod number and pod weight per plant in wider spacing treatment was mainly due to sufficient space between rows which encouraged the production of more vigorous plants and also lesser interplant competition for space, light, nutrient and moisture. They reported that plant geometry did not alter the shelling percentage during the three years of study and that closer spacing of 30 x 10 cm recorded higher pod yield as compared to wider spacing of 45 x 10 cm. They further attributed this to the maintenance of optimum population load per unit area. Similar results of higher groundnut pod yield due to optimum plant population had been reported by Agasimani *et al*. (1984). They observed that optimum population per unit area was required to harvest the maximum pod yield and attributed the reduction in pod yield in wide row spacing to the lower plant population per unit area.

Weed control is difficult in rows too narrow to cultivate. Kalra *et al*. (1984) found that narrow row culture called for higher plant densities that ensured faster canopy development to compete successfully against weeds. The use of narrow rows appears to be one of a series of steps that has led to higher crop yields for producers. However, to obtain a high yield response from narrow row widths, the producer must have adopted other managerial tools leading to high yields by using adapted varieties, fertilization, weed and insect control, timely cultural practices, uniform plant distribution within the row, and optimum plant densities (Agasimani *et al*., 1984, Kalra *et al*., 1984, Ramesh and Sabale, 2001). Plant breeders and crop physiologists are attempting to identify genotypes adapted to high plant densities and narrow rows (Mock and Pearce, 1975).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Location/Site

The experiment was conducted at the Plantation Section of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, in April, 2007, August, 2007 and July, 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 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 commence in September and end in midNovember with a peak in October at which period dry desiccating harmattan winds blow across the area from the north. The rainfall regimes are separated by a period of dry weather from

December to March. The area also has a mean temperature range of 21°C to 30°C (Meteorological Department of Kumasi Metropolitan Assembly – KMA, Kumasi, 2007). The land was previously cultivated to cassava and left fallowed for one year.

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. In this light, clay is frequently found and quartz merging with weathered rock with small mica flakes and light yellowish mottles.

3.2. Experimental Design and Treatments

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.

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 x 20cm (250,000 plants/ha)

S2: Spacing of 30cm x 30cm (111,111 plants/ha)

S3: Spacing of 30cm x 45cm (74,740 plants/ha)

In all, there were thirty six plots in each of the three trials carried out. 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. The area of the field was 656.5m^2.

3.3. Cultural/management practices

The land which had been under fallow for two cropping seasons from cassava cultivation was ploughed and disc harrowed two weeks after ploughing using a tractor.

Seeds obtained from the Crop Research Institute (CRI) were tested for viability by percentage germination test. A hundred seed selected at random from the seed lot were sown in a shallow furrow and covered with soil lightly. Fourteen days after sowing, the number of germinated seedlings was counted. The percentage germination was computed 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 2ndMay, 2008 in the 2007 seasons and the major season of 2008.

- Refilling: - Filling of vacancies was done one week after sowing.
- Thinning: - Seedlings were thinned to one plant per hill two weeks after germination.
- Fertilizer application: - Single superphosphate at a rate of 50 kg/ha was applied four weeks after planting by side dressing.
- Pests and disease control: - Rodents were serious pests during the experiment and scarecrows were, therefore, used to ward them away.
- Weed management: - 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.

3.4. Data collected

3.4.1. Soil analysis

Soil samples were taken from the experimental site to a depth of 30cm and analysed for pH and other chemical and physical properties.

1. **pH**

   The pH was determined with a NK_2 pH (Model 290) meter using a soil to water ratio of 1:2:5.

2. **Organic Matter**

   Organic carbon was determined by the Walkley – Black method (Nelson and Sommers, 1982). This was multiplied by 1.724 (Van Bemmelen factor) to give the organic matter content.

3. **Available phosphorus**

   Available phosphorus was determined by extracting soil with Bray P_1 extractant (0.025N HCl and 0.03N H_4F). This was shaken for about one minute and the solution filtered. The P in the extract was determined by phosphomolybdate Calorimetric method using Bausch and Lomb Spectronic 20 spectrophotometer.

4. **Exchangeable Potassium and Sodium**

   The soil was extracted with 1.0N NH_4OAc at pH 7 and the extract analysed for K^+ and Na^+ by Flame Photometer.

5. **Exchangeable Ca and Mg**

   These exchangeable cations were determined in the laboratory by EDTA titration after extraction with 1.0N NH_4oAc solution at pH 7.

6. **Total Nitrogen**

Total nitrogen was determined by the macro – Kjeldahl digestion, distillation and titration method.

Total N was calculated using the formula:-

$$\text{Total N in the sample} = \frac{14\,(A-B) \times N \times 100}{1000 \times W}$$

Where,

A = Volume of standard acid used in titration
B = Volume of standard acid used in blank titration

N = Normality of the standard acid

W = Weight of soil sample used

Data were collected two weeks after planting and at two weeks interval till harvesting for the three seasons. There were 5 sampling periods. At each sampling period, five plants were sampled per plot for plant height, shoot dry matter per plant, number of branches and nodules per plant.

3.4.2. Plant height

Five plants were randomly selected and tagged from each treatment. The height of each of the plants was measured with a metre rule from the ground level to the tip of the tallest leaf. The mean plant height was then computed by summing up the heights of the five tagged plants and then dividing the total height by five.

3.4.3. Shoot dry matter per plant

Five plants were randomly selected from each treatment and the dry weights of the shoot (leaves and stems) were determined by oven-drying them at a temperature of 80^{o}C for 48 hours. The dry weight of the shoot was repeatedly taken until a constant weight was obtained. The mean shoot dry matter per plant was then computed by dividing the total weight of the five pants by five.

3.4.4. Mean number of branches per plant

Five plants were randomly selected from each treatment and the number of branches was counted. The mean number of branches was then calculated.

3.4.5. Number of nodules per plant

Five plants were randomly selected from each treatment and the number of nodules was counted with a hand lens. The mean number of nodules was then calculated by dividing the total number of nodules of the five plants by five.

3.4.6. Pod yield

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.

3.4.7. Shelling percentage

The shelling percentage was obtained by expressing seed weight as a percentage of pod weight.

3.4.8. Percentage pod formation or pod setting

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.

3.4.9. Harvest index

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).

3.4.10. Number of well-filled pods per plant

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 wellfilled pods per plant.

3.4.11. Number of seeds per pod

After hand-shelling, the total number of seeds per plant was divided by the mean number of filled matured pods per plant.

3.4.12. Hundred seed weight

Three seed lots were counted randomly from each of the treatments and their 100-seed weights taken using an electric balance. The average of the three seed lots was subsequently weighed.

3.4.13. Grain yield

The dry weight of the seeds was taken with an electric balance after hand-shelling the dry pods. The dry weight of the seeds was repeatedly taken until a constant weight was obtained.

3.4.14. Total dry matter yield

The total dry matter yield was determined by adding the total shoot dry matter to total dry pod weight.

3.4.15. Number of flowers per plant

Five plants per treatment were tagged prior to flowering and the number of flowers produced per plant was recorded daily from commencement of flowering to cessation of flowering for each treatment and the mean was calculated.

3.4.16. Fertility co-efficient

Fertility co-efficient denoted by the ratio of number of pods formed to the total number of flowers produced per plant was estimated.

3.4.17. Number of unfilled and immature pods per plant

Unfilled and immature pods stripped from sampled plants were counted. The total number was divided by the number of plants harvested per square metre per each treatment to get mean number of unfilled and immature pods per plant.

3.5. Data analysis

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

CHAPTER FOUR

4.0 RESULTS

4.1. Soil chemical properties

The experimental site had a pH of 5.6. It also contained 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. The values for pH, organic matter and potassium were moderate, while the others were low (SRI, 2007).

Table 4.1: Chemical properties of soil samples (30cm depth) from experimental sites and guide to interpretation of levels

Nutrient	Level	Rank/Grade
pH	5.6	Moderately acidic

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

4.2. Climatic conditions at Experimental sites

The total annual rainfall amount for 2007 and 2008 were 1999.1mm and 1160.9mm, respectively. Again, the total maximum annual temperatures for 2007 and 2008 were 377.5 ºC and 384.1 ºC, while the total minimum annual temperatures were 259.5 ºC and 261.0 ºC.

Table 4.2: Climatic data during the growth period of 2007

Month	**Rainfall (mm)**	**Temp. (°C)**		**Relative humidity %**	
		Max.	**Min.**	**0900 hr**	**1500 hr**
January	8.5	24.0	20.2	60	34
February	65.3	34.5	22.4	80	55
March	76.7	35.2	22.6	89	49
April	189.9	34.0	22.5	82	58
May	84.3	32.9	22.5	83	63

June	244.2	31.6	21.6	85	65
July	374.0	29.7	20.8	85	70
August	127.3	29.0	20.5	86	72
September	539.8	32.2	21.5	88	71
October	237.6	30.9	21.7	86	67
November	48.6	31.4	21.8	82	62
December	2.9	32.1	21.4	83	55
Total	1999.1	377.5	259.5	989	721

Table 4.3: Climatic data during the growth period of 2008

Month	**Rainfall (mm)**	**Temp. (°C)**		**Relative humidity %**	
		Max.	**Min.**	**0900 hr**	**1500 hr**
January	0.0	33.3	19.2	48	32
February	61.7	34.6	21.7	79	49
March	134.1	34.2	22.6	81	53
April	117.1	33.3	22.9	83	59
May	185.8	33.0	22.8	82	59
June	179.8	31.4	22.5	85	64
July	45.0	28.8	22.3	88	68
August	114.5	29.5	20.8	88	69
September	148.9	30.0	21.3	87	68
October	95.8	31.3	21.6	85	62

November	30.7	32.7 22.2	84 55
December	47.5	32.0 21.1	84 53
Total	1160.9	384.1 261.0	974 622

4.3. Vegetative Growth

4.3.1. Plant height

The weed-free treatment (W3) and the widest spacing (S3) significantly (P<0.05) increased plant height, while the least plant height was obtained in the no-weeding and the closest spacing at most of the sampling periods (Figures 4.1 and 4.2). Plant height increased with time in both seasons of 2007, but the rate at which it increased was faster at the first two sampling periods after which the increment reduced. Plant height was higher in the minor season than in the major season of 2007.

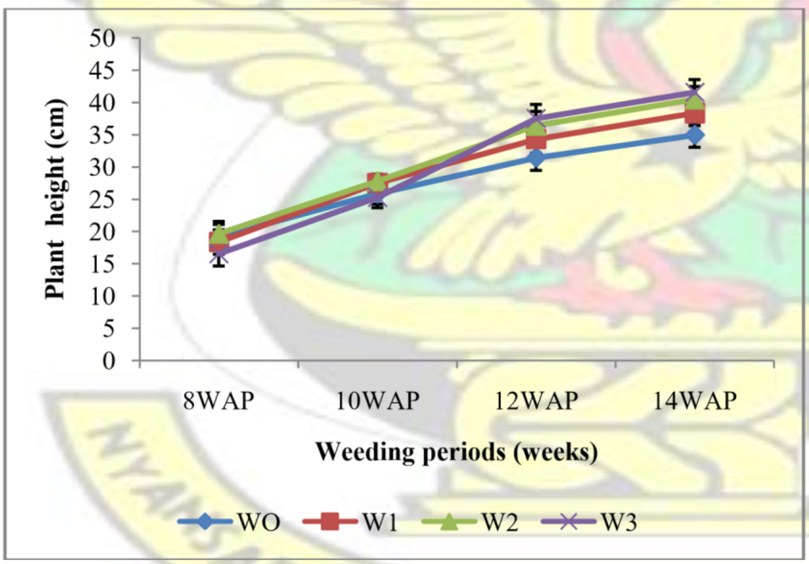

Fig 4.1a: Effect of weeding on plant height during the major season of 2007 Bars indicate LSD (5%)

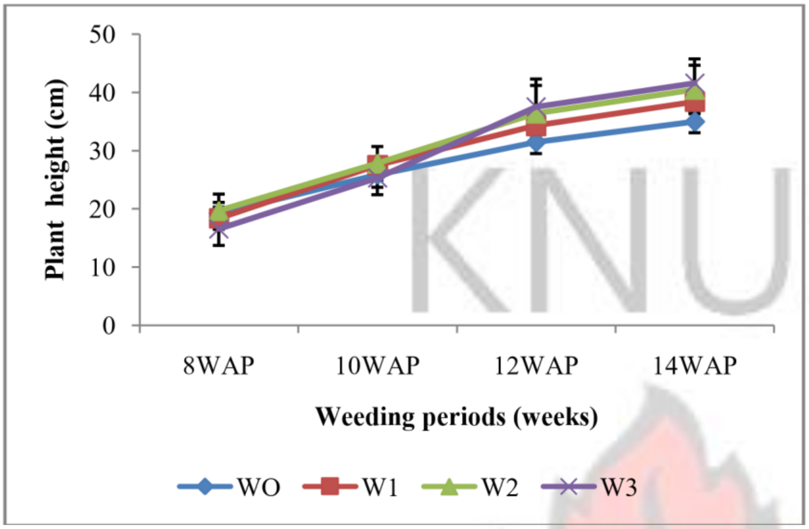

Fig 4.1b: Effect of weeding on plant height during the minor season of 2007 Bars indicate LSD (5%)

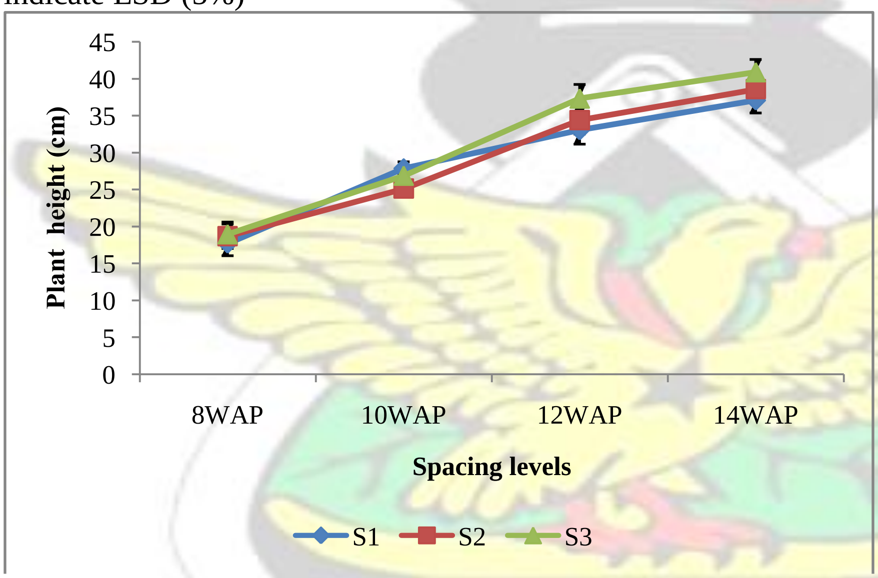

Fig 4.2a: Effect of spacing on plant height during the major season of 2007 Bars indicate LSD (5%)

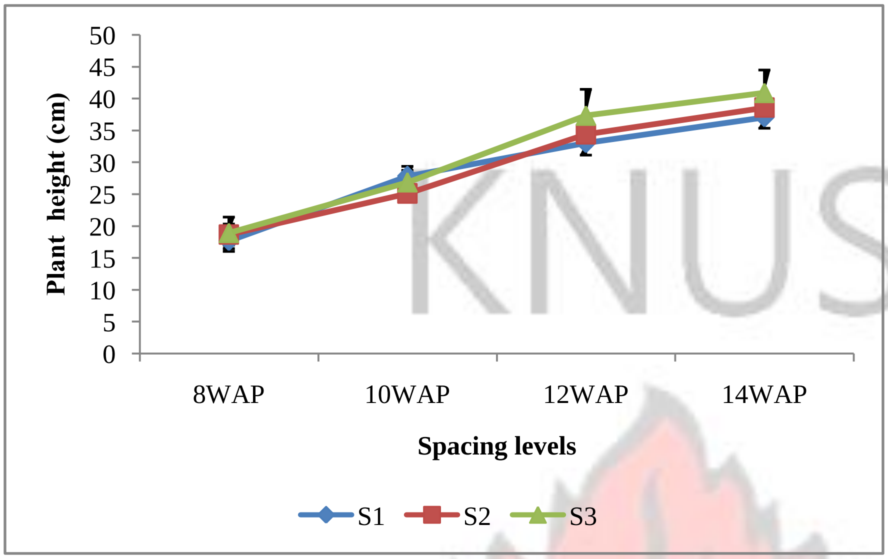

Fig 4.2b: Effect of spacing on plant height during the minor season of 2007
Bars indicate LSD (5%)

4.3.2. Shoot Dry Matter Production

Both weeding and spacing significantly ($P<0.05$) increased shoot dry matter per plant in both seasons of 2007 (Figures 4.3 and 4.4). The highest shoot dry matter per plant was recorded by the weed-free treatment (W3) and the widest spacing (S3), while the least shoot dry matter per plant was produced by the no-weeding treatment (W0) and the closest spacing (S1) throughout the period. Shoot dry matter production per plant increased up to 10 WAP and declined thereafter in both seasons of 2007.

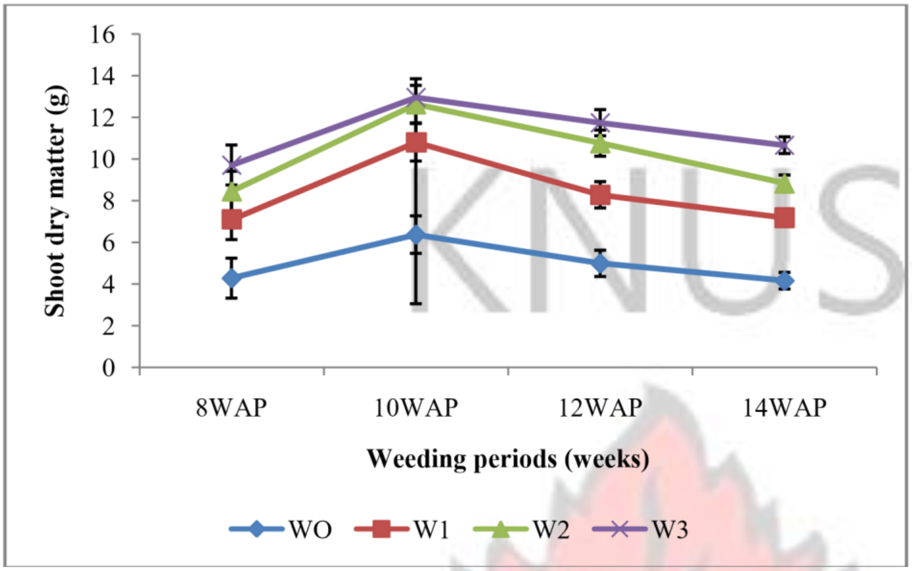

Fig 4.3a: Effect of weeding on shoot dry matter during the major season of 2007 Bars indicate LSD (5%)

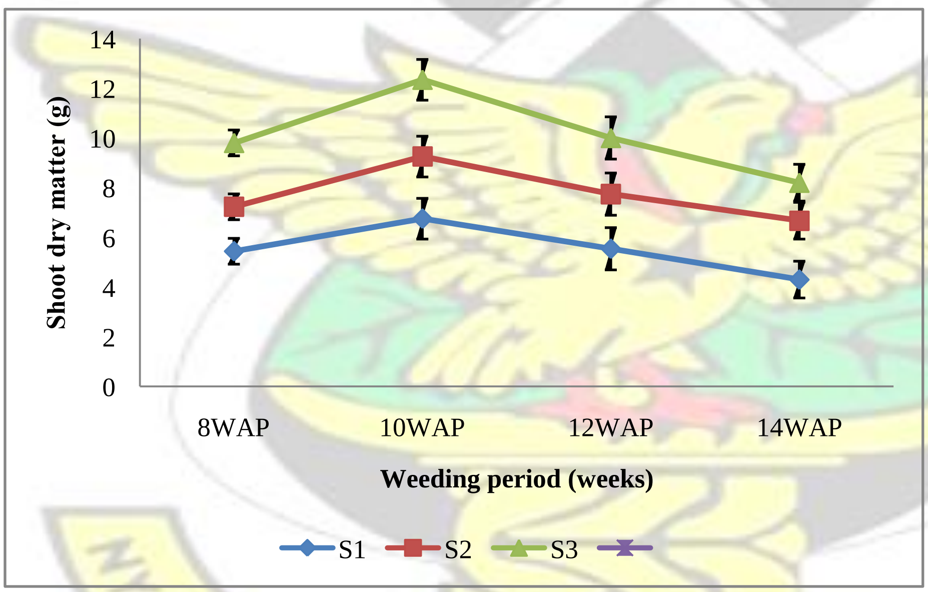

Fig 4.3b: Effect of weeding on shoot dry matter during the minor season of 2007 Bars indicate LSD (5%)

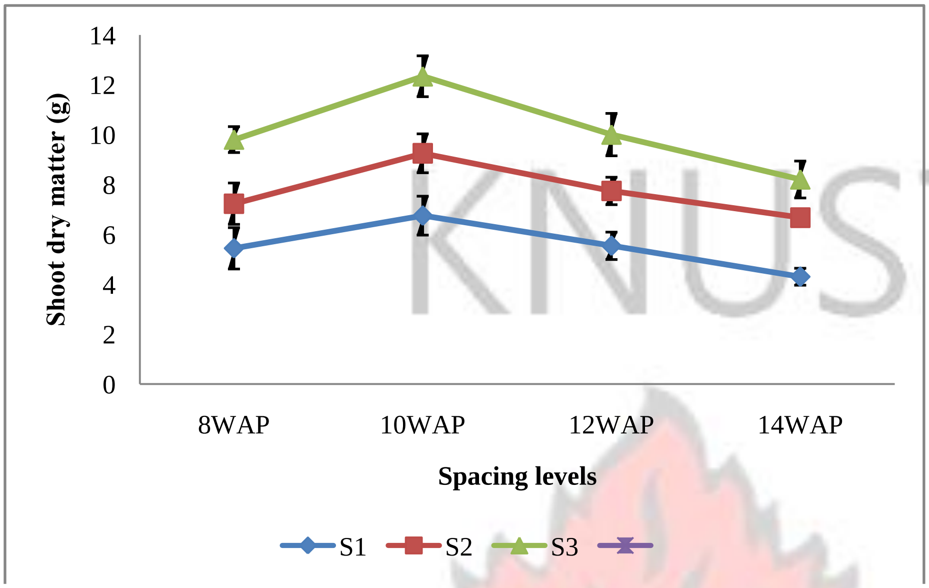

Fig 4.4a: Effect of spacing on shoot dry matter during the major season of 2007 Bars indicate LSD (5%)

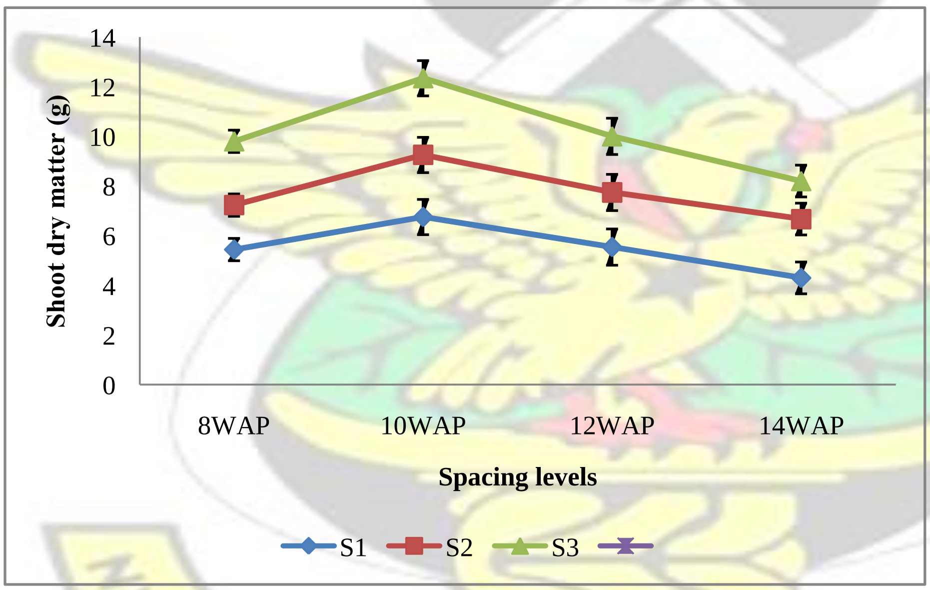

Fig 4.4b: Effect of spacing on shoot dry matter during the minor season of 2007 Bars indicate LSD (5%)

4.3.3. Number of branches and nodules per plant

In 2007 major season, the weed-free treatment (W3) and the widest spacing (S3) gave the highest number of branches and nodules per plant, while the no-weeding or control (W0) and the closest spacing (S1) recorded the least number of branches and nodules per plant (Table 4.4). Similar trend was observed in 2007 minor season. The results for 2008 showed a similar trend as in the 2007 trials, except that spacing did not significantly (P>0.05) affect the number of branches per plant in 2008 major season (Table 4.5).

Table 4.4: The effect of weeding and spacing on number of branches and nodules per plant in 2007 major and minor seasons

Treatment	No. of branches per plant		No. of nodules per plant	
	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007
Weeding				
W0	4.49	5.62	60.20	52.40
W1	5.98	5.89	117.10	111.80
W2	5.90	5.73	135.90	131.20
W3	6.67	6.88	162.80	156.40
LSD (5%)	0.34	0.27	20.42	20.30
Spacing				
S1	5.56	5.44	104.50	99.00
S2	6.03	6.08	126.00	118.60
S3	6.43	6.57	126.50	121.30
LSD (5%)	0.29	0.23	17.69	17.58
Grand mean	6.01	6.03	119.00	113.00
CV (%)	5.70	4.50	17.60	18.40

Table 4.5: The effect of weeding and spacing on number of branches and nodules per plant in 2008 major season

Treatment	No. of branches	No. of nodules
Weeding		
W0	5.39	63.60
W1	7.33	124.00
W2	6.78	143.10
W3	7.89	169.90
LSD (5%)	1.27	20.07
Spacing		
S1	6.42	110.30
S2	6.88	131.70
S3	7.25	133.50
LSD (5%)	1.10	17.38
Grand mean	6.85	125.20
CV (%)	18.90	16.40

4.4. Yield and yield components

4.4.1. Pod yield

Results showed significant effect (P<0.05) with weeding and spacing (Tables 4.6 and 4.7). 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 March 2007, August 2007 and May 2008 (Tables 4.6 and 4.7). 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 three seasons of study.

4.4.2. Shelling percentage

No-weeding (control) gave a shelling percentage which was significantly (P<0.05) the lowest and differed from the other weeding treatments, but did not vary significantly in both seasons of 2007. The highest shelling percentage was associated with weeding 2-3 weeks after planting (W1), weeding 3-4 weeks after planting (W2) and weed-free in both trials of 2007. Spacing had no significant (P>0.05) influence on shelling percentage in August, 2007. The closest spacing (S1) gave he highest shelling percentage in both seasons of 2007, while the lowest was obtained in the intermediate spacing (S2) as in March, 2007 and the widest spacing (S3) in August, 2007 (Table 4.6).

Results of shelling percentage showed significant effect (P<0.05) with treatment application in May, 2008. The weeding 3-4 weeks after planting treatment (W2) and the closest spacing (S1) gave the highest values (Table 4.7). The least shelling percentage was observed in the noweeding treatment (W0) and the widest spacing (S3).

4.4.3. Percentage pod formation

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 both trials (Table 4.6). The weed-free treatment (W3) of March, 2007 and weeding 2-3 weeks after planting (W1) of August, 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 March, 2007. In August 2007, spacing varied significantly (P<0.05) in percentage pod formation. The widest spacing gave the highest percentage pod formation, while the least percentage pod formation was found in the closest spacing in both seasons of 2007 (Table 4.6).

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 May, 2008 (Table 4.7).

4.4.4. Harvest index

Spacing did not have any significant influence (P>0.05) on harvest index in both the major and minor seasons 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 noweeding treatment (control) recorded the lowest harvest index (0.21) in the major season of 2007. In the minor season of 2007, the no-weeding treatment (W0) differed significantly (P<0.05) from the other weeding treatments. The highest harvest index of 0.39 was observed in weeding 2-3 weeks after planting (W1), while the no-weeding treatment (control) had the lowest harvest index of 0.24 (Table 4.6).

Harvest index was significantly affected (P<0.05) by weeding in May 2008 (Table 4.7). 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 May, 2008. However, harvest index increased as spacing was narrowed (Table 4.7). 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 4.6: The effect of weeding and spacing on pod yield, shelling percentage, percentage pod formation and harvest index of groundnut in 2007 major and minor seasons

Treatment	Pod yield (kg/ha)		Shelling %		% pod formation		Harvest index	
	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007
Weeding								
W0	414.0	378.0	55.80	57.10	16.80	13.05	0.21	0.24
W1	1198.0	890.0	68.40	73.90	40.80	40.33	0.34	0.39
W2	1357.0	1264.0	68.40	71.60	39.50	30.38	0.35	0.38
W3	1580.0	1605.0	64.20	76.10	41.10	36.55	0.40	0.35
LSD (5%)	143.3	124.0	7.16	7.02	8.65	4.53	0.05	0.05
Spacing								
S1	1357.0	1299.0	69.70	71.40	27.10	18.55	0.34	0.35
S2	1064.0	953.0	59.60	69.90	32.20	31.77	0.33	0.33
S3	991.0	851.0	63.30	67.80	44.40	39.91	0.33	0.34
LSD (5%)	124.1	108.1	6.20	6.08	7.49	3.92	0.04	0.04
Grand mean	1137.00	1034.00	64.20	69.70	34.60	30.08	0.33	0.34
CV (%)	12.90	12.30	11.40	10.30	25.60	15.40	14.20	14.70

Table 4.7: The effect of weeding and spacing on the pod yield, shelling percentage, percentage pod formation and harvest index of groundnut in 2008 major season

Treatment	Pod yield (kg/ha)	Shelling %	% pod formation	Harvest index
Weeding				
W0	376.0	65.64	36.60	0.32
W1	3960.0	74.84	57.30	0.40
W2	4684.0	75.12	70.10	0.35
W3	5179.0	68.59	70.20	0.32
LSD (5%)	932.6	4.93	9.09	0.05
Spacing				
S1	4637.0	74.10	53.80	0.36
S2	3374.0	69.96	57.60	0.35
S3	2637.0	69.09	64.20	0.33
LSD (5%)	807.6	4.27	7.87	0.04
Grand mean	3550.00	71.05	58.50	0.35
CV (%)	26.90	7.10	15.90	13.90

4.4.5. Number of pods per plant

In the growing seasons of 2007 (Table 4.8) and May, 2008, weeding and spacing significantly (P< 0.05) influenced number of pods per plant (Figures 4.5a and 4.5b). The weed-free treatment (W3) of all the three seasons and the weeding 3-4 weeks after planting treatment (W2) of March 2007 produced the highest number of pods per plant, while the no-weeding treatment (W0) gave the least in all the three 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 March, 2007, August 2007 (Table 8) and May, 2008 (Figures 4.5a and 4.5b). The highest treatment interaction effect was observed in the weed-free and widest spacing (W3S3) in all the three seasons of study, while the least was obtained by the no-weeding and intermediate spacing (W0S2) in both seasons of 2007 (Table 8) and the no-weeding and the closest spacing (W0S1) in May, 2008 (Figures 4.5a and 4.5b).

4.4.6. Number of seeds per pod and hundred seed weight

Number of seeds per pod was not significantly affected (P>0.05) by weeding and spacing in both seasons of 2007 (Table 4.8) and the major season of 2008 (Figures 4.6a and 4.6b). No clear trend was established by the treatments imposed.

Spacing did not have any significant influence (P>0.05) on hundred seed weight in March, 2007, August, 2007 and May, 2008. However, hundred seed weight responded significantly (P<0.05) to weeding in 2008 (Figures 4.7a and 4.7b), but was not significantly affected (P>0.05) by weeding in both seasons of 2007 (Table 4.8). The highest hundred seed weight was shown in the weed-free, weeding 2-3 weeks after planting treatments and the widest spacing, while the noweeding (W0) and the intermediate spacing (S2) produced the lowest value (Figures 4.7a and 4.7b).

4.4.7. Grain yield

Results showed that grain yield was significantly (P<0.05) affected by weeding and spacing in both seasons of 2007 (Table 8) and the major season of 2008 (Figures 4.8a and 4.8b). The weedfree 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 noweeding and widest spacing (W0S3) had the least.

Table 4.8: The effect of weeding and spacing on yield and yield components of groundnut in 2007 major and minor seasons

Treatment	No. of pods per plant		No. of seeds/pod		Hundred seed wt.		Grain yield kg/ha	
	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007
Weeding								
W0	2.95	2.80	2.06	2.08	31.89	30.81	236.0	217.0
W1	12.75	10.70	1.99	2.13	31.84	31.18	820.0	665.0
W2	16.14	19.80	1.98	2.03	31.97	31.20	934.0	905.0
W3	16.14	21.30	2.02	2.06	31.92	31.77	1034.0	1231.0
LSD (5%)	2.84	6.21	0.13	0.13	1.60	0.93	122.7	125.1
Spacing								
S1	5.98	7.40	2.01	2.11	31.64	31.14	969.0	967.0
S2	10.44	13.30	2.00	2.04	31.84	31.39	651.0	689.0
S3	17.28	20.30	2.03	2.08	32.18	31.20	648.0	608.0
LSD (5%)	2.46	5.38	0.11	0.11	1.38	0.81	106.2	108.3
Grand mean	11.23	13.70	2.01	2.07	31.89	31.24	756.00	755.00
CV (%)	25.90	46.50	6.60	6.40	5.10	3.10	16.60	17.00

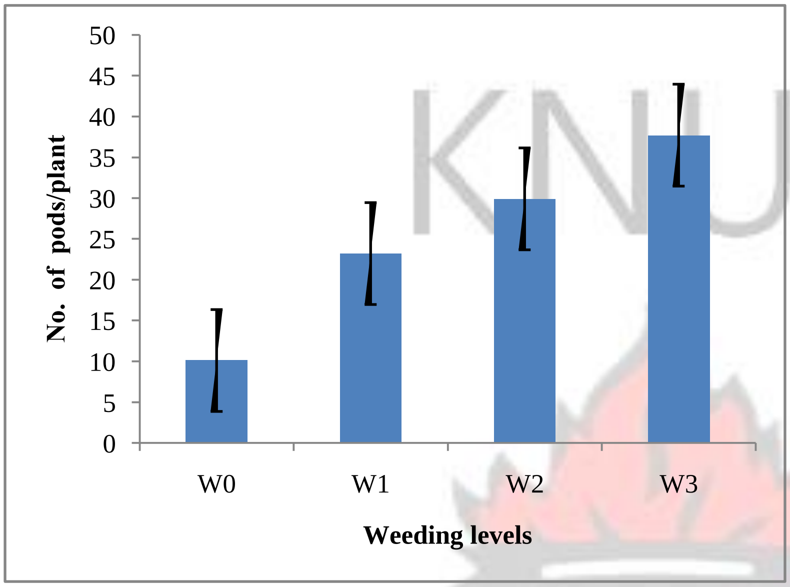

Figure 4.5a: The effect of weeding on number of pods per plant in the major season of 2008 LSD at 5% was 6.24.

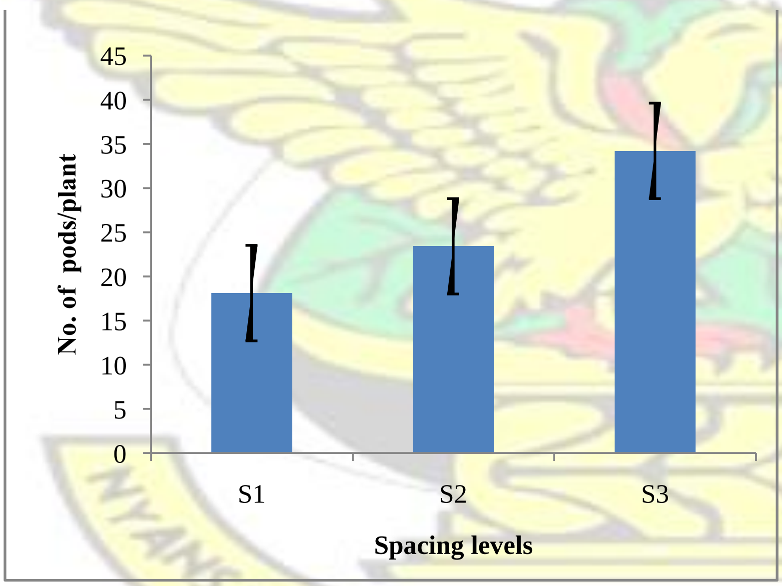

Figure 4.5b: The effect of spacing on number of pods per plant in the major season of 2008 LSD at 5% was 5.40.

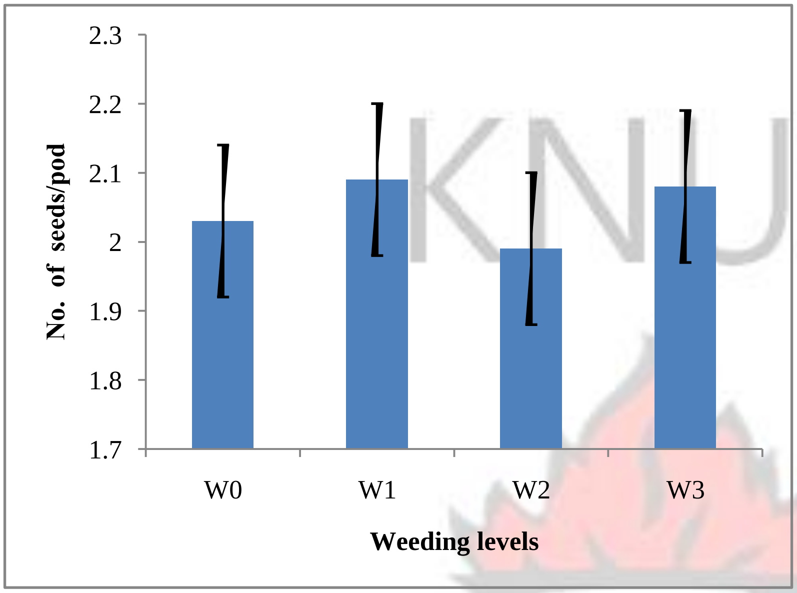

Figure 4.6a: The effect of weeding on number of seeds per pod in the major season of 2008 LSD at 5 % was 0.11.

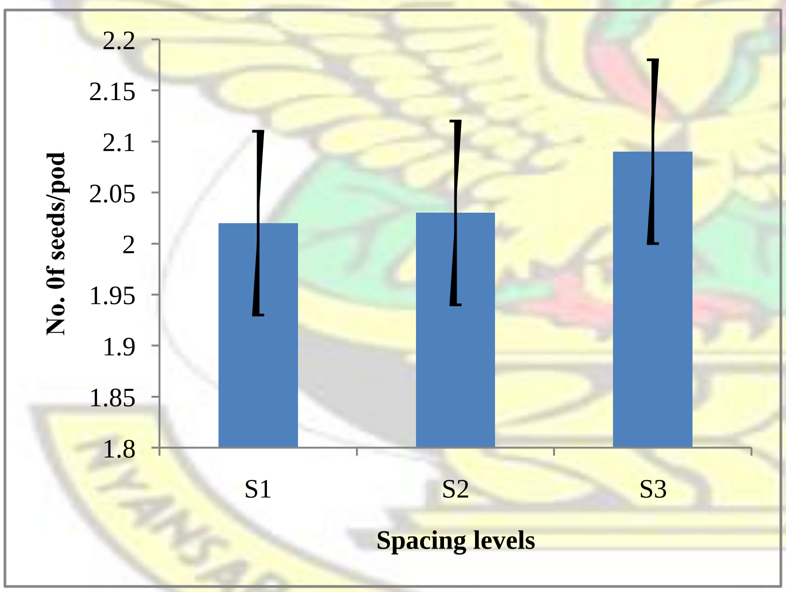

Figure 4.6b: The effect of spacing on number of seeds per pod in the major season of 2008 LSD at 5% was 0.09.

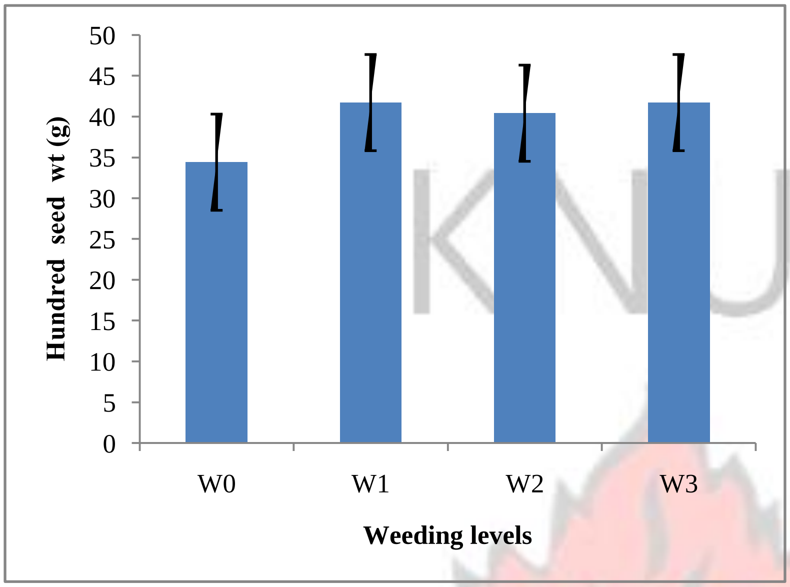

Figure 4.7a: The effect of weeding on hundred seed weight in the major season of 2008 LSD at 5% was 5.89.

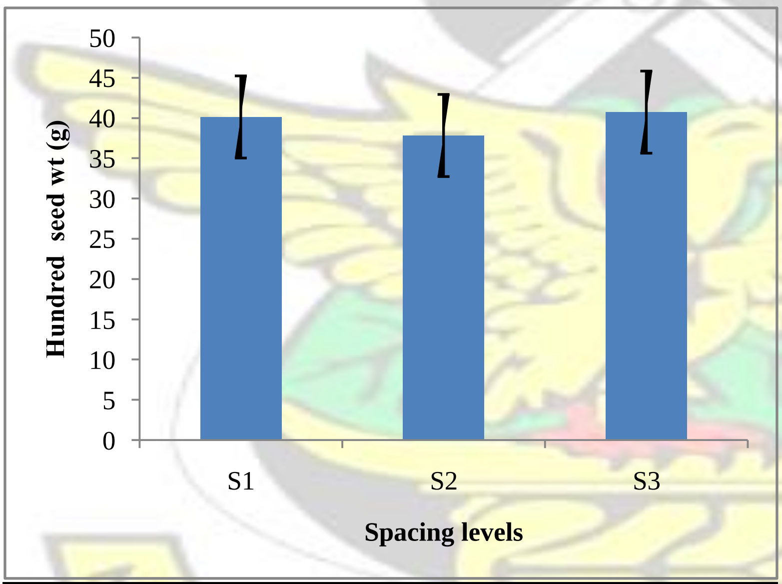

Figure 4.7b: The effect of spacing on hundred seed weight in the major season of 2008 LSD at 5% was 5.10.

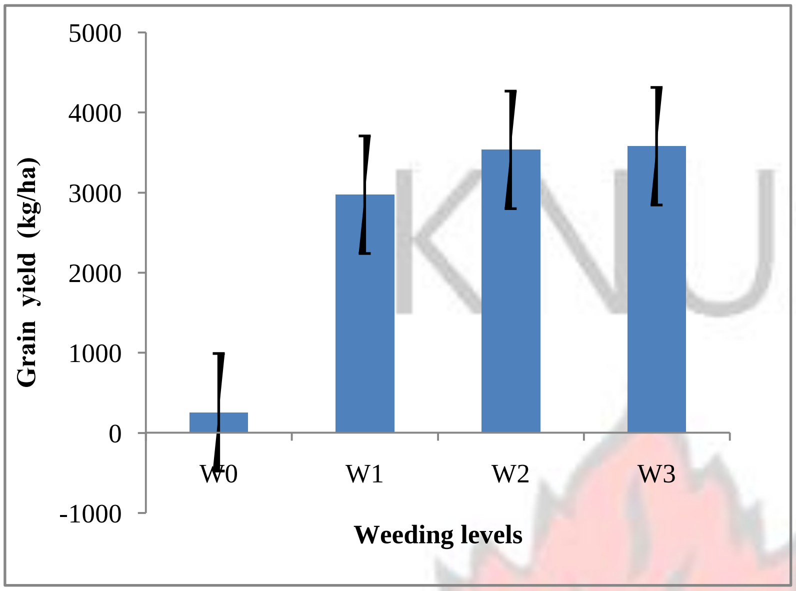

Figure 4.8a: The effect of weeding on grain yield in the major season of 2008 LSD at 5% was 734.70.

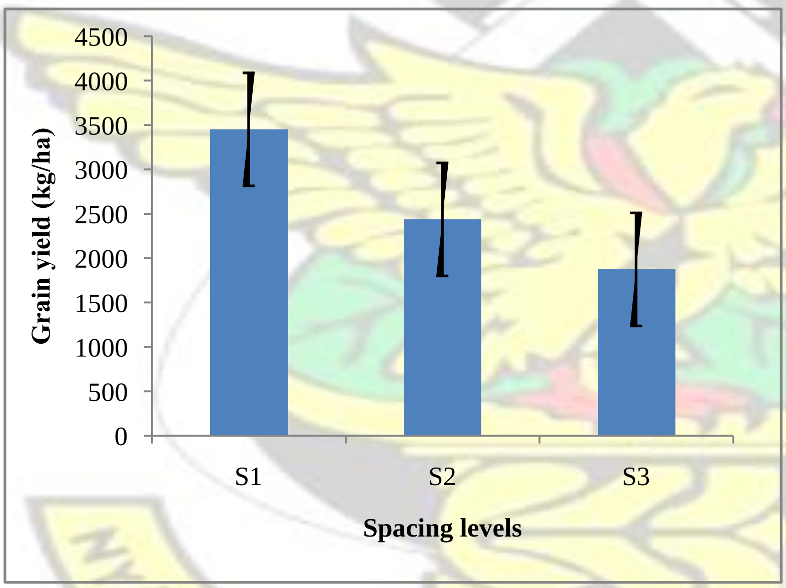

Figure 4.8b: The effect of spacing on grain yield in the major season of 2008

LSD at 5% was 636.30.

4.4.8. Total Dry Matter Yield

Total dry matter yield followed similar trend as pod and grain yields in the major and minor seasons of 2007 and major season of 2008. 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 all the three seasons of study (Tables 4.9 and 4.10). 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 all the three 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 (Tables 4.9 and 4.10).

4.4.9. Number of flowers and fertility co-efficient

Results of number of flowers per plant showed that the weed-free treatment (W3) of March, 2007 and weeding 3-4 weeks after planting (W2) treatment of August, 2007 significantly (P<0.05) recorded the highest (Table 4.9). The highest fertility co-efficient was recorded by the weed-free treatment (W3) and weeding 2-3 weeks after planting (W1) treatment in both seasons of 2007. However, the no-weeding treatment gave the lowest number of flowers per plant and fertility co-efficient in both seasons of 2007. The highest number of flowers and fertility coefficient were also found in the widest spacing, while the closest spacing gave the least (Table 4.9). Spacing did not significantly affect (P>0.05) the number of flowers per plant in both seasons of 2007. However, significant differences were established among spacing treatments for fertility co-efficient in both seasons of 2007.

Results of the number of flowers per plant and fertility co-efficient showed significant effect

(P<0.05) with treatment application in 2008. The number of flowers per plant and fertility coefficient were highest in the weed-free treatment (W3) and widest spacing (S3), while the noweeding (W0) and the closest spacing (S1) gave the least value (Table 4.10).

4.4.10. Number of unfilled and immature pods per plant

The no-weeding and closest spacing treatments produced the greatest number of immature and unfilled pods in both seasons of 2007. However, the least number of immature and unfilled pods was recorded by the weed-free and weeding 3-4 weeks after planting treatments as well as the intermediate spacing of March, 2007 and widest spacing of August, 2007 (Table 4.9).

The number of unfilled and immature pods per plant was not significantly influenced (P>0.05) by weeding and spacing in the major season of 2008. However, the highest value was found in the weeding 2-3 weeks after planting (W1) and the widest spacing (S3), while the least was produced by the weeding 3-4 weeks after planting (W2) and the closest spacing (S1) treatments (Table 4.10).

Table 4.9: The effect of weeding and spacing on total dry matter yield (TDMY), number of flowers per plant, fertility co-efficient and number of immature and unfilled pods in 2007 major and minor seasons

Treatment	Total dry matter yield (kg/ha)		No of flowers/plt		Fertility co-efficient		No. of immature and unfilled pods	
	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007	Mar. 2007	Aug. 2007
Weeding								
W0	983.0	938.0	19.10	18.70	0.17	0.17	4.04	6.83
W1	1934.0	2083.0	36.40	31.40	0.35	0.34	1.25	5.69
W2	2576.0	2455.0	38.00	68.00	0.34	0.29	1.00	3.56
W3	3054.0	2918.0	42.30	62.00	0.35	0.33	1.00	2.33
LSD (5%)	122.3	115.5	7.57	20.41	0.07	0.03	0.11	2.34
Spacing								
S1	2794.0	2612.0	27.60	37.20	0.22	0.21	1.90	5.12
S2	1948.0	1932.0	34.90	48.70	0.29	0.27	1.75	5.46
S3	1661.0	752.0	39.30	49.10	0.40	0.36	1.82	4.06
LSD (5%)	105.9	100.0	6.56	17.68	0.06	0.03	0.09	2.03
Grand mean	213.00	2099.00	33.90	45.00	0.30	0.28	1.82	4.60
CV (%)	5.90	5.60	22.80	46.40	24.50	11.50	6.10	52.10

Table 4.10: The effect of weeding and spacing on total dry matter production (TDMY), number of flowers per plant, fertility co-efficient and number of immature and unfilled pods in 2008 major season

Treatment	Total dry matter production(kg/ha)	No of flowers per plant	Fertility co-efficient	No of immature and unfilled pods
Weeding				
W0	779.0	34.8	0.30	11.56
W1	7484.0	46.6	0.50	12.56
W2	10020.0	48.0	0.61	8.83
W3	11037.0	57.4	0.63	12.00
LSD (5%)	1311.7	7.9	0.08	4.14
Spacing				
S1	9446.0	39.3	0.46	10.46
S2	6851.0	45.2	0.50	10.75
S3	5693.0	55.7	0.57	12.00
LSD (5%)	1135.9	6.8	0.07	3.58
Grand mean	7330.0	46.70	0.51	11.56
CV (%)	18.30	17.30	15.90	37.60

4.5. Correlation between yield and yield components

4.5.1. Weeding and correlation matrix

The weeding treatment showed that total dry matter was positively correlated with seed yield (r=0.948), number of pods per plant (r=0.972), number of seeds per pod (r=0.957) and hundred seed weight (r=0.667) (Table 4.11).

Table 4.11: The effect of weeding on correlation matrix between total dry matter and yield components

	100seed weight	Harvest index	Seed yield	No. of pods/plant	Pod yield	Shelling %	No. of seeds/pod
100-seed weight							
Harvest index	0.785						
Seed yield	0.869	0.967					
No. of pods/plant	0.803	0.996	0.984				
Pod yield	1.000	0.785	0.869	0.803			
Shelling %	-0.984	-0.692	-0.818	-0.723	-0.984		
No. of seeds/pod	0.845	0.990	0.993	0.997	0.845	-0.774	
Total dry matter	0.667	0.962	0.948	0.972	0.667	-0.594	0.957

4.5.2. Spacing and correlation matrix

Total dry matter had positive correlation with seed yield (r=0.972) and number of seeds per pod (r=0.920), but negatively correlated with hundred seed weight (r=-0.911) and number of pods per plant (r=-0.922) with spacing treatment (Table 4.12).

Table 4.12: The effect of spacing on correlation matrix between total dry matter and yield components

	100seed weight	Harvest index	Seed yield	No. of pods/plant	Pod yield	Shelling %	No. of seeds/pod
100-seed weight							
Harvest index	0.930						
Seed yield	-0.788	-0.959					
No. of pods/plant	1.000	0.940	-0.804				
Pod yield	-0.886	-0.994	0.984	-0.898			
Shelling %	-0.504	-0.786	0.929	-0.528	0.847		
No. of seeds/pod	-0.676	-0.899	0.987	-0.696	0.941	0.977	
Total dry matter	-0.911	-0.999	0.972	-0.922	0.998	0.816	0.920

CHAPTER FIVE

5.0. DISCUSSION

5.1. Treatment effects on vegetative growth

5.1.1. Plant height

The study revealed that plant height increased with time in the experiment of the three seasons. The study gave a mean plant height of 32.78cm and 38.83cm for March, 2007 and August, 2007, respectively (Figures 4.1 and 4.2). The results are in agreement with work by Kochhar (1986) who observed that the general plant height of groundnut was within a range of 30 to 60cm. Plant height was comparatively higher in August, 2007 probably due to the higher rainfall (777.4mm) recorded in 2007 minor growing season as against 328.5mm in the major season of 2007 during the active vegetative growth period of the plant. The highest plant height of 38.68cm and 41.56cm in March, 2007 and August, 2007, which was associated with the weed-free treatment (W3), could be caused by a reduction in competition for available resources like nutrients and water. The widest spacing (30cm x 45cm) gave the greatest plant height of 39.67cm and 40.88cm in March, 2007 and August, 2007, respectively. The results obtained were probably due to a lower plant population and less interspecific competition for available resources. This observation agrees with the work on confectionery groundnut by Kathirvelan and Kalaiselvan (2007) who stated that plant height increased linearly with wider row spacing as a result of reduced interspecific competition.

5.1.2. Shoot dry matter per plant

Results indicated that shoot dry matter production per plant increased in the weed-free (W3) and widest spacing (S3) than the other treatments (Figures 4.3 and 4.4). The highest shoot dry matter production per plant recorded by the weed-free treatment could be attributed to the higher number of branches per plant and reduced competition for resources and space which encouraged the production of more vigorous plants with more shoots. Work by Kalra *et.al*. (1984) supports this claim. The results also agree with the work of Chaniyara *et.al*. (2001) who found that lesser interplant competition for resources which resulted in more partitioning efficiency and overall growth of the plants could account for higher shoot dry matter in the widest spacing. Results showed that shoot dry matter increased, reached a peak and then declined with time in the three seasons of the experiment. The increment could be due to adequate production of vegetative components such as leaves, stems and overall gain in dry matter yield. Contrary, leaf fall (senescence), competition and mutual shading of leaves could result in a reduction in shoot dry matter during the later stages of growth. This collaborates with the work done on confectionery groundnut by Sathyamoorthi *et al.* (2007) who stated that shoot dry matter changes with time. Furthermore, the experiment of 2008 major season characterized by the lowest amount of rainfall (Table 4.3) did better than the trial of 2007 in shoot dry matter per plant probably because the former was more efficient in dry matter partitioning. Suitable soil conditions, inherent soil fertility and the residual influence of applied fertilizer in the preceding season could contribute to the results.

5.1.3. Number of branches per plant

At maturity, the highest number of branches per plant of 6.67, 6.88, and 7.89 for March, 2007, August, 2007 and 2008 major season, respectively was found in the weed-free treatment (W3). The greatest value (Tables 4.4 and 4.5) recorded by the weed-free treatment could be attributed to less competition for nutrients, moisture, space and irradiance. The results also showed that the highest number of branches per plant (6.43, 6.57 and 7.25) for March, 2007, August, 2007 and 2008 major season, respectively was found in the widest spacing (S3). This observation is consistent with the findings of Kathirvelan and Kalaiselvan (2007) who observed that under the widest spacing, there could be more feeding zone which may have encouraged lateral growth resulting in the production of more number of branches per plant. Conversely, Kathirvelan and Kalaiselvan (2007) noted that close spacing (20cm x 20cm) could intensify intra-plant competition and reduce the feeding zone which could result in lower number of branches per plant.

5.1.4. Number of nodules per plant

Results of this work showed that the number of nodules per plant increased under the weed-free treatment and the widest spacing (Tables 4.4 and 4.5). Adequate supply of soil nutrients, moisture, and oxygen may have encouraged ramifying root system, activities and populations of rhizobia. This finding is in collaboration with work by Ramesh and Sabale (2001) who observed an extensive root growth and development and an increased number of nodules per plant through the supply of adequate resources.

5.2. Treatment effects on yield and yield components

5.2.1. Pod and Grain yields

The weed-free treatment (W3) recorded the highest pod yields of 1580 kg ha^{-1}, 1605 kg ha^{-1} and 5179 $kgha^{-1}$ in March, 2007, August, 2007 and 2008 major season, respectively. Similarly, the highest grain yields of 1034 kg ha^{-1}, 1231 kg ha^{-1} and 3579 kg ha^{-}1 in March, 2007, August, 2007 and 2008 major season, respectively were found in the weed-free treatment (Tables 4.6, 4.7 and 4.8 and Figure 4.8). 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 weeding treatment showed that there was a positive correlation between total dry matter and yield and yield components. This indicated that a rise in total dry matter as a result of weeding would culminate in a corresponding increase in seed yield, number of seeds per pod, number of pods per plant and hundred seed weight and vice versa (Table 4.12).

However, the no-weeding treatment (control) produced the least pod yield of 414 kg ha^{-1}, 378 kg ha^{-1} and 376 kg ha^{-1} in March, 2007, August, 2007 and 2008 major season, respectively. The least grain yield of 236 kg ha^{-1}, 217 kg ha^{-1} 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 collaborate 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 and minor seasons of 2007 and the major season of 2008 were 73.80%, 76.45% 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}(March, 2007), 1299 kg ha^{-1} (August, 2007) and 4637 kg ha^{-1} (2008 major season). For grain yield, the greatest values of 969 kg ha^{-1}, 967 kg ha^{-1} and 3449 kg ha^{-1} for March, 2007, August, 2007 and 2008 major season, 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 widerow 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 4.10) 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).

Spacing produced a positive correlation between total dry matter and seed yield and number of seeds per pod. These results showed that a rise in total dry matter would result in a corresponding increase in seed yield and number of seeds per pod and vice versa (Table 4.12). However, spacing produced a negative correlation between total dry matter and hundred seed weight and number of pods per plant indicating that an increase in total dry matter would lead to a corresponding fall in hundred seed weight and number of pods per plant and vice versa (Table 4.12).

The widest spacing (30cm x 45cm) gave the least pod yield of 991 kg ha^{-1}, 851 kg ha^{-1} and 2637 kg ha^{-1} with the lowest grain yields of 648 kg ha^{-1}, 608 kg ha^{-1} and 1872 kg ha^{-1} for March, 2007, August, 2007 and 2008 major season, 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 collaborates 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 March, 2007 and August, 2007 with a combination of weeding 3-4 weeks after planting and closest spacing recording the greatest pod and grain yields in 2008 major season.

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 noweeding (control) and the widest spacing may be due to the combined effect of greater weedcrop competition and lower plant population per unit area.

Again, results showed that the 2008 major season trial, with the lowest rainfall amount, recorded the highest pod and grain yields (Table 4.7, and Figure 4.8). The mean grain yield in 2008 of 2585 kg/ha as against 756 kg/ha and 755 kg of March, 2007 and August, 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.

5.2.2. Number of pods per plant

Results showed that the number of pods per plant (16.1, 21.3 and 37.7 for March, 2007, August, 2007 and 2008 major season, 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 three 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. The results collaborate with the work of Ramesh and Sabale (2001), Subrahmaniyan *et al.* (2000) and Sathyamoorthi *et al.* (2007). 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.

5.2.3. Number of seeds per pod

Number of seeds per pod was not influenced by weeding and spacing. Number of seeds per pod is a varietal characteristic, controlled largely by plant genetic factors (Ahmad and Mohammad, 1997, Ogundele, 1988). However, weeding 2-3 weeks after planting treatment recorded the highest number of seeds per pod in the August, 2007 (Table 4.8) presumably due to low competition for resources. Although spacing did not affect the number of seeds per pod, the closest spacing 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 closest spacing, fewer number of pods per plant are produced which could increase the number of seeds per pod. Generally, the August, 2007 had the highest number of seeds per pod because of higher rainfall and adequate temperature (Table 4.3) recorded during the period of pod filling.

5.2.4. Hundred-seed weight

Though weeding did not influence hundred seed weight in March, 2007 and August, 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 4.8) 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 spacing in the in both 2007 and 2008.

However, the highest hundred seed weight was associated with the widest and the intermediate spacing. 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 widest spacing, sufficient moisture and lesser competition led to efficient dry matter partitioning.

Hundred seed weights were comparatively higher in the 2008 major season trial. This could be caused by the early incidence of drought (Table 4.3) 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 67 to 70g obtained by Frimpong *et al.* (2006) but was consistent with that reported by Borget (1992) with an average seed weight range of 3050 g.

5.2.5. 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 (Tables 4.6 and 4.7) 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, lower incidence of pests and diseases and efficient allocation of assimilates. The results also showed that the closest spacing (S1) 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 higher shelling percentage through favourable rainfall distribution and better soil-water relations.

5.2.6. Percentage pod formation

The highest percentage pod formation (Tables 4.6 and 4.7) recorded by weed-free (W3) and weeding 2-3 weeks after planting (W1) in the experiment of the three 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 three seasons (Tables 4.6 and 4.7). 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.

5.2.7. Harvest index

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. Similarly, „Florunner‟ showed a 20% increase in seed yield over „Early Runner‟, due to a harvest index of 0.41; and in
1977 „Early Bunch‟ was introduced with a 10% increase in seed yield over „Florunner‟, due to a harvest index of about 0.51.

The results indicated that harvest index was higher (0.39 and 0.40) in weeding 2-3 weeks after planting treatment for August, 2007 and May, 2008, respectively. Weed-free treatment had the highest harvest index (0.40) in March, 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 the 2008 major season. 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 which may have encouraged 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.

5.2.8. Total dry matter yield

The weed-free treatment gave the highest total dry matter yield of 3054 kg ha^{-1}, 2918 kg ha^{-1} and 11037 kg ha^{-1} in March, 2007, August, 2007 and 2008 major season, 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}, 2612 kg ha^{-1} and 9446 kg ha^{-1} in March, 2007, August, 2007 and May, 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}, 938 kg ha^{1} and 779 kg ha^{-1} in March, 2007, August, 2007 and May, 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 three 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 (Table 4.3).

5.2.9. Number of flowers per plant and Fertility co-efficient

Results indicated that weeding treatments increased number of flowers and fertility co-efficient over the control treatment in the trials. The results obtained could be due to the reduction of weed biomass culminating in maintenance of adequate soil moisture and optimum soil temperature to prevent flower abortion. Work of Norman *et. al*. (1996) supports this assertion. Weeding also raised the number of branches per plant which could contribute to the greater number of flowers and other yield attributes. The interplay of all these factors together with favourable soil conditions may have encouraged pod setting and development leading to improved fertility co-efficient.

Furthermore, the widest spacing recorded the highest number of flowers per plant and fertility co-efficient in the experiment of the three seasons (Tables 4.9 and 4.10). This could be due to the higher number of branches per plant, sufficient space between rows which encouraged the production of more vigorous plants and also lesser interplant competition for resources. Subrahmaniyan *et al.* (2000) and Sathyamoorthi1 *et al.* (2007) found that in peanuts, increasing row spacing improved number of flowers per plant and fertility co-efficient due reduced interplant competition for resources.

5.2.10. Number of unfilled and immature pods per plant

Results of the number of unfilled and immature pods per plant showed that the no-weeding treatment recorded the highest value in March, 2007 and August, 2007, respectively. The results could be due to intense competition for resources, defoliation and inefficient dry matter partitioning. This is in agreement with the work of Lavabre *et al*. (1991) who found that the competitive and allelopathic effect of weeds reduced dry matter partitioning which affected pod filling. In 2008, the weeding 2-3 weeks after planting gave the highest results. The results could be attributed to the highest number of pegs and pods which could not be filled properly perhaps as a result of intra-plant competition for resources during the period of pod filling. The closest spacing recorded the highest number of unfilled and immature pods per plant in March, 2007 and August, 2007, respectively due to intra-plant competition for resources. However, the widest spacing produced the highest number of unfilled and immature pods per plant in the major season of 2008. This could be due to inefficient dry matter partitioning resulting from intra-plant competition for resources. The results are supported by Subrahmaniyan *et al.* (2000) who observed that the closest spacing was associated with unfilled and immature pods due to intraplant competition for resources.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATIONS

6.1. Summary

- The results showed that weeding had a greater influence on growth and yield of groundnuts over no-weeding treatment.
- The results of the study revealed that the weed-free consistently had the highest plant height, shoot dry matter per plant, number of branches and nodules per plant in the experiment of the three seasons.
- The weed-free treatment recorded the highest pod, grain and total dry matter yields in the experiment of the three seasons. The number of pods per plant increased in the weed-free treatment in all the seasons of the experiment, but had the same value with weeding 3-4 weeks after planting treatment in March 2007. The weeding treatments increased shelling percentage and hundred seed weight over the control treatment in all the seasons of the experiment. The greatest percentage pod formation was recorded by weed-free in March, 2007 and May, 2008, respectively, while weeding 2-3 weeks after planting had the highest in August, 2007.
- The greatest harvest index was recorded by the weed-free treatment in March 2007, while weeding 2-3 weeks after planting recorded the highest in August, 2007 and May, 2008, respectively. The no-weeding marginally increased number of seeds per pod in March,

2007. Again, the highest number of seeds per pod was recorded by the weeding 2-3 weeks after planting in August, 2007 and May, 2008, respectively.

- The results further revealed that the widest spacing (30cm x 45cm) recorded the highest plant height, number of branches, number of nodules and shoot dry matter per plant in all the three seasons of the experiment.
- The widest spacing had the highest number of pods, number of flowers, fertility coefficient and percentage pod formation throughout the study.
- The closest spacing (20cm x 20cm) gave the highest pod, grain and total dry matter yields, shelling percentage and harvest index throughout the study. Results indicated that hundred seed weight was marginally increased by the widest spacing in March, 2007 and 2008 major season, respectively, while the intermediate spacing (30cm x 30cm) recorded the highest in August, 2007. The highest number of seeds per pod was produced by the closest spacing in August, 2007, while the widest spacing recorded the greatest number of seeds per pod in March, 2007 and May, 2008, respectively.
- The weeding treatment showed that total dry matter was positively correlated with seed yield (r=0.948), number of pods per plant (r=0.972), number of seeds per pod (r=0.957) and hundred seed weight (r=0.667).
- Similarly, total dry matter had a positive correlation with seed yield (r=0.972) and number of seeds per pod (r=0.920), but negatively correlated with hundred seed weight (r=-0.911) and number of pods per plant (r=-0.922) with spacing treatment.
- The best treatment interaction was observed in the weed-free and closest spacing (W3S1) for pod and grain yields in March, 2007 and August, 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 all the three seasons.

6.2. Conclusion

Farmers should adopt the weed-free and the closest spacing treatments since they produced the highest pod and grain yields in the experiment of all the three seasons.

6.3. Recommendation

The study was conducted in a semi-deciduous forest zone with „Ochrosol" type of soil. The variety of groundnut used throughout the study was "Chinese Shitaochi". It is, therefore, recommended that further work should be conducted in multi agro-ecological zones to expand varietal (Mani pinta, Atebubu local, Nkoranza local, Dagomba, hypogaea) response to weeding and spacing. The treatments applied were weeding (No-weeding or control, weeding 2-3 weeks after planting, weeding 3-4 weeks after planting and weed-free) with spacings of 20 cm x 20 cm, 30 cm x 30 cm and 30 cm x 45 cm. 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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