RESPONSE OF GROUNDNUT (*Arachis hypogaea* L.) VARIETIES TO WEED MANAGEMENT STRATEGIES AND TIME OF PHOSPHORUS FERTILIZER APPLICATION IN NORTHERN GUINEA AND SUDAN SAVANNA, NIGERIA

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE IN AGRONOMY

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JANUARY, 2022

DECLARATION

I declare that the work in this Thesis entitled '**RESPONSE OF GROUNDNUT (*Arachis hypogaea*** L.) **VARIETIES TO WEED MANAGEMENT STRATEGIES AND TIME OF PHOSPHORUS FERTILIZER APPLICATION IN NORTHERN GUINEA AND SUDAN SAVANNA, NIGERIA'** has been performed by me in the Department of Agronomy. The information derived from the literature is duly acknowledged in the text and list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other University.

Dahiru Mohammed JIBRIN ____________________ ________________
Name of Student Signature Date

The above declaration is confirmed

Dr. U.L. Arunah________________ ________________________ ________________
Chairman, Supervisory Committee Signature Date

CERTIFICATION

The Thesis entitled '**RESPONSE OF GROUNDNUT (*Arachis hypogaea* L.) VARIETIES TO WEED MANAGEMENT STRATEGIES AND TIME OF PHOSPHORUS FERTILIZER APPLICATION IN NORTHERN GUINEA AND SUDAN SAVANNA, NIGERIA'** by Dahiru Mohammed JIBRIN meets the regulations governing the award of the degree of Doctor of Philosophy in Agronomy of the Ahmadu Bello University, Zaria and is approved for its' contribution to knowledge and literary presentation.

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This work is dedicated to my late father, Alhaji Mohammed Babandi Jibrin, my mother, Hajiya Hauwa Jibrin, my wife Safiya Aminu Ahmed and my entire family members for their support.

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ABSTRACT

Field trials were conducted in 2018 and 2019 wet seasons at the Teaching and Research farm of Samaru College of Agriculture, Ahmadu Bello University, Zaria Kaduna State and the Minjibir Research farm of Agricultural Research Station, Kano State of the Institute for Agricultural Research , Ahmadu Bello University, Zaria, to evaluate the response of groundnut varieties to weed management strategies and time of phosphorus fertilizer application in the northern Guinea and Sudan savanna of Nigeria. The treatments consisted of three groundnut varieties (SAMNUT-22, SAMNUT-23 and SAMNUT-24), five weed control management strategies (weedy check; black polythene mulch; pendimethalin at 1.5 kg a.i. ha^{-1} as pre- emergence herbicide followed by (fb) fluazifop-p-butyl at 1.0 kg a.i ha^{-1} applied at 3 WAS; intra-row spacing at 10 cm; hoe weeding at 3 and 6 WAS); and two different times of phosphorus (P) fertilizer application (i.e 2 weeks before sowing and at sowing). The treatments were arranged in a split plot design with factorial combinations of weed control strategies and time of P application in the main plot, and groundnut variety were allocated to the sub-plots. The treatments were replicated three times. The most predominant weed species in Samaru at 2018 and 2019 were *Oldenlandia herbacea*, *Vernonia cinerea*, *Ludwigia abyssinica* and *Ageratum conyzoides*, while in Minjibir at both years the most predominant weed species were *Oldenlandia herbacea*, *Alternanthera sessilis*, *Hyptis lanceolata*, *Commelina diffusa* subsp. *diffusa*. The results from the study revealed that SAMNUT-24 recorded the least weed dry weight, weed cover score and had better weed control efficiency than SAMNUT-22 and SAMNUT-23. Furthermore, SAMNUT-24 had wider canopy spread, taller plants, higher crop growth rate (CGR) and leaf area index (LAI), more nodules and better crop vigour compared with the two other varieties. The same variety flowered earlier and produced the highest pod and haulms yield. Evaluating weed management strategies; use of black polythene as mulch conferred significantly advantages with respect to weed control efficiency, low weed dry weight, weed cover score, higher CGR, LAI, canopy spread, pod yield, haulm yield, kernel yield and other yield components. Also, higher relative growth rate and nodule count were recorded under with black polythene mulch and hoe weeding at 3+ 6 WAS than in other weed control methods. Time of P application had no significant effect on weed, growth and yield characters evaluated. Groundnut pod yield was positively and highly correlated with haulm yield. In conclusion, the use of SAMNUT-24 with black polythene mulch and applying P 2 weeks before sowing or at sowing gave the highest yield of 2.50 t ha^{-1} at Samaru and 2.41 t ha^{-1} at Minjibir. Also, the use of SAMNUT-24 with black polythene mulch and applying P at sowing gave the highest net farm income at Samaru (₦ 1,405,643) and Minjibir (₦ 1,434,036) respectively. The following recommendations are drawn from the study; SAMNUT-24 is recommended for better pod and haulms yield groundnut. For effective weed control black polythene mulch or hoe weeding at 3 and 6 WAS are recommended for boosting productivity of groundnut. Application of phosphorous fertilizer at sowing is recommended for minimizing cost of production around Samaru and Minjibir.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Production Trend

Groundnut (*Arachis hypogaea* L.) is a member of the genus *Arachis* in the family Fabaceae. Although groundnut originated in South America, it is now widely planted in tropical, sub-tropical and warm temperature areas in Asia, Africa, North and South America, and Oceania (Freeman *et al.*, 1999). Groundnut is an important food crop worldwide with an annual production of over 53.6 million tonnes on nearly 31.5 million hectares in 2020, according to the Food and Agriculture Organization (FAOSTAT, 2020). The crop's cultivation, processing and trade significantly impact the socio-economic development of a large number of developing and least developed countries (Tyrolers, 2018). Approximately 60% of the world production comes from Asia, whereas Africa accounts for 26%. In 2017, groundnut productivity was the lowest in Africa (839.6 kg ha^{-1}) compared to the rest of the world (1685.6 kg ha^{-1}) FAOSTAT. (2017). However, Nigeria is the largest groundnut producing country in West and Central Africa, accounting for 51% of the production in the region with 3.27 million tonnes of groundnut production annually. The country contributes 10% of total global production and 39% of that of Africa (Ajeigbe *et al.,* 2015; Rilwanu, 2019).

According to Anon. (2020), groundnut in Nigeria is mainly grown in the northern States; however, some few southern States also produce small amounts. The major groundnut producing States in Nigeria are Nasarawa, Niger, Kano, Jigawa, Katsina, Benue, Taraba, Gombe, Adamawa and Zamfara. Furthermore, the national average yield of groundnut was 1.24 t ha^{-1} for both 2019 and 2020. The estimated land area cultivated to groundnut in 2020 was 3,596,420 hectare which is an increase of 0.5% over 3,578,670 ha under groundnut cultivation in 2019 Anon. (2020).

1.2 Uses

Groundnut is an important subsistence food crop throughout the tropics. It is mainly grown for the kernels, edible oil, cake and vegetative residue derived from it. Groundnut kernels typically contain oil (47 – 53%), protein (25 – 36%), carbohydrate (10 – 15%), are rich in phosphorus and a good source of vitamins B and E (Prasad *et al.*, 2010). According to latter author's, groundnuts are used in various forms, which include groundnut oil, roasted and salted groundnut, boiled or raw groundnut or as paste popularly known as groundnut (peanut) butter. The tender leaves are used in certain parts of West Africa as vegetable in soups. Groundnut oil is the most important product of the crop and it is used for both domestic and industrial purposes. About 75% of the world groundnut production is use in extraction of edible oil.

In the northern Guinea and Sudan savanna zones of Nigeria, apart from being consumed whole, edible groundnuts are processed into or used as an ingredient in a wide range of other products. These include groundnut oil, groundnut cake (*kuli kuli)*, salted groundnut (*gyada mai gishiri)*, a gruel or porridge made with millet and groundnut (*kunun gyada)*, groundnut candy *(kantun gyada)* and groundnut soup (*miyar gyada)* (Mukhtar, 2009).

According to Mukhtar (2009) groundnut haulms are used as livestock feed as the haulms are an important product often equal in value to the pods in the semi urban areas of the Sudano-Sahelian zone of Nigeria. In such areas they provide substantial cash income for small holders farmers. The shells are used for fuel by some local oil factories or spread on the field as a soil amendment. They could also be used as bulk in livestock rations or in making chipboard for use in joinery (Mukhtar, 2009).

1.3 Production Constraints

Nigeria is one of the largest producers of groundnut in the world. It is estimated that over two million hectares of land are planted to groundnut in both the rainforest and savanna agro-ecological zones of the country (Opeke, 2006). Groundnut pod yield from farmers' fields under rain fed conditions are low, averaging 910 kg ha^{-1} (Anon., 2013) and national average of 1.24 t ha^{-1} for both 2019 and 2020 (Anon. 2020) when compared to the potential yield of 3,000 kg ha^{-1}. Groundnut yield is as high as 3000 kg ha^{-1} in the USA, contrasting the yield in tropical Africa which is about 800 kg ha^{-1} and traceable to weed infestation (Akobundu,1987). Uncontrolled weed growth in this crop results in yield losses which are as high as 60% to 80% (Ikisan, 2000; Reddy and Reddy, 1990).

Groundnut being mainly grown during the rainy season by peasant farmers in Nigeria, encounters several weed problems since the annual grasses and seasonal broad leaf weeds grow luxuriantly and dominate cultivated lands during this season as compared to the summer season. The weed competition in early stages of groundnut is maximum because of the slow initial foliage growth which depends on the degradation of food reserve in the cotyledons. Although emergence of radicle in groundnut is fast (24 hrs for pish, 36 – 48 hrs for Virginia type), root development is slow (5 – 10 days). The root is capable of absorbing nutrients and the epicotyl is exposed to light in groundnut whereas the reverse is the case with the weeds which emerge faster and grow rapidly as compared with groundnut and consequently take a lead in crop – weed competition. The critical period of weed competition is estimated to be between 2 and 6 weeks after sowing (WAS).

According to Ahmed *et al.* (2010), the main problems limiting production of groundnut are poor cultural practices and inadequate weed management. In view of these constraints, it is important to evolve an integrated approach involving combinations of improved soil fertility (including time of fertilizer application), crop varieties and weed control strategies with closer spacing that could prove effective in the production of groundnut under rain fed conditions in the Sudan and northern Guinea savanna agro-ecological zones of Nigeria.

Weeds have consistently been one of the major constraints faced by farmers in the production of groundnut. For instance, uncontrolled weed growth has been reported to cause significant yield loss which is as high as 51% (Etejere *et al*., 2013). Aside from yield reduction, Manickam *et al*. (2001) observed that, unweeded control plots have produced the lowest N, P and K uptake of 169.4, 3.6 and 52.2 kg ha^{-1} by groundnut, respectively.

Factors that restrict the availability of phosphorus to crops are soil pH, soil texture, amount of P applied to soil, presence of other elements like iron, aluminum, manganese and calcium in the soil, microbial activity and time of P application (Yash *et al.,*1992). Among these factors, time of P application is important in soils with either low or high pH conditions because P applied at land preparation is less available to crops than that applied at the time of sowing (Amanullah and Khalil.,2010).

1.4 Justification of the Study

In spite of the availability of abundant land and human resources in Nigeria, yield per hectare from groundnut production (in shell) is below world average (National average yield of groundnut was 1.24 t ha^{-1} for both 2019 and 2020) (Anon, 2020). It has been revealed that, there is a shortfall of over 90 percent of groundnut requirement by companies involved in processing (Anon, 2004). Among other agronomic factors, low-yielding varieties are the major constraints in groundnut production and quality (Asofo- Adjei *et al*., 1998).

The use of improved varieties for a particular ecology is essential in groundnut production. Farmers using improved varieties have derived significant yield gains 31% over local varieties in Nigeria (Anon, 2011). Improved seed is a necessary vehicle for transforming high groundnut yields among the farming communities and with the introduction of improved varieties, both groundnut area and productivity in the world increased from 29,757,612 ha^{-1} and 51.4 tonnes ha^{-1} in 2018 to 31,568,626 ha^{-1} and 53.6 tonnes ha^{-1} in 2020, respectively (FAO, 2020).

Effective weed control is essential for profitable groundnut production. Weeds compete for moisture, nutrients and light during the growing season thereby lowering the quality and quantity of the crop. Losses caused by weeds vary from one country to another and even within one ecology to the other, depending on the predominant weed flora and on the control methods employed (Ibrahim, 2015).

Groundnut competes poorly with weeds especially during the first six weeks after sowing (WAS) because at that period groundnut plant cannot compete with weeds for growth factors. There is a need, therefore, for early weed control for better yield. The average yield loss due to weeds has been reported to be about 30% and may reach up to 60% under poor management practices. It is advantageous to control weeds on groundnut fields during the early stage of the crop growth. A combination of two or more control measures may provide better results and is more economical (Ajeigbe *et al*., 2015).

Hoe weeding is still by far the most widely used and predominant method of weed control in groundnut throughout the tropics. However it is expensive, labour intensive and availability of labourers are often scarce particularly at the peak of the season. With rapid industrialization and urbanization, human labour is rapidly becoming scarce and expensive for commercial farming. It may not be effective in reducing yield loss because hoe weeding may damage pegs and roots and reduce crop yield.

In areas where agricultural labour is scarce and costly, herbicides may be used as pre- and post- emergence application to control weeds (Rao, 2004). Pre-emergence application of pendimethalin/metolachlor at the rate of 0.75 kg a.i ha^{-1}, alachlor at the rate of 1.0 kg a.i ha^{-1}, or pre-plant incorporation of fluchloralin at the rate of 0.75 kg a.i ha^{-1} controlled weeds effectively (Rao, 2004).

In modern agriculture, application of black plastic mulch film is becoming popular as a means of weed control, soil nutrient and moisture conservation and most of all very good results (yield) have been achieved particularly in rain fed agriculture (Bhardawaj and Sarolia, 2012; Mohapatra *et al.*, 1999). Likewise, the use of white and green covering had little effect on weeds, whereas brown, black, blue or white on black (double colour) films prevent weeds from emerging (Bond and Grundy, 2001; Bhardwaj and Sarolia, 2012).

Ramakrishna *et al.* (2006) reported that effective weed control using mulch resulted in improved yield parameters and yield of groundnut. Earlier harvest is among the most important advantage of polythene mulch application (Roe *et al.*, 1994). Also the mulching resulted in early flowering, production of more flower, pegs, pods, 100- kernel mass and pod yield when compared to un-mulched plots (Devi Dayal *et al.*, 1991; Choi and Chung, 1997).

Crop can be favoured in competition against weed by use of narrow rows and/or higher population densities, which eventually hastens the rapidity of closure of the canopy and enhance canopy radiation interception, thereby increasing crop growth rates and yields (Andrade *et al*., 2002) and suppressing weed growth and competitiveness (Murphy *et al.*,1996; Zimdahl, 1999; Mashingaidze, 2004). The suppression of growth (dry weight) of weeds by narrow row has been reported in a number of studies (Teasdale, 1995; Begna *et al.*, 2001*;* Tharp and Kells, 2001; Alford *et al.*,2004).

Jat *et al*. (2011) also reported that a good crop cover by adopting right inter row (30 cm in bunch type and 45 cm in spreading type) and intra row (10 cm) spacing will smother the growth of the weeds. Singh and Bajpai (1991) reported that large leaf and better smothering effect of crop prevent the weeds from utilizing sufficient resources such as light, moisture and nutrient resulting in lesser dry weight of weeds.

Generally, the timing of fertilizer application is one of the principles guiding efficient crop yield. Proper timing of fertilizer application increases yields; nutrient use efficiency and prevents damage to the environment (Guy, 2017). Phosphorus plays many essential plant processes, including reproduction, photosynthesis, cell division, root development and energy storage, thus aid good crop growth and high yields. Phosphorus is noted especially for its role in capturing and converting the solar energy into useful plant compounds (Cockfield *et al*., 1988). It also assists the root absorption of N required for plant growth and development.

Ayodele and Oso (2014) reported that applied P at the early stage of cowpea growth stimulated root elongation and proliferation, nodule formation and development of vegetative structures as well as uptake of other plant nutrients; since phosphorus plays vital roles in the reactions involving energy transfer, leguminous crop which depends on fixed N for growth would require large amount of phosphorus at the right time.

According to Ramozemana, (1999) time of P fertilizer application significantly increased pod dry weight per plant, relative to the zero P treatment, if supplied within 2 WAS. If supplied during this period, pod dry weights were increased by a factor of 6 – 7. If applied 4 WAS, however, pod yields were no longer significantly affected. Within both shoot and pod dry matter weight, positive effects of P fertilizer were clearly restricted to application during the first 2WAS.

Productivity increase in groundnut production in the semi-arid tropics depends on the amount of phosphorus in the soil, amount and distribution of rainfall received and seed viability.

Based on the foregoing, the objective(s) of this study therefore are as follows;

1.5 Objectives of the Study

1. To determine the performance of groundnut variety under the northern Guinea and Sudan savanna conditions in Nigeria.

2. To determine the most efficient among the weed control method for optimum groundnut yield in the northern Guinea and Sudan savanna agro-ecological zones of Nigeria.

3. To determine the most appropriate time of P application for optimum groundnut yield in the northern Guinea and Sudan savanna agro-ecological zones of Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Growth and Yield of Groundnut as Influenced by Varietal Differences

One of the major constraints attributed to groundnut production in Africa generally is the use of low yielding cultivars that are prone to disease and pest attack at all stages of production by resource poor farmers. According to Nautiyal *et al.* (1999) the key factor affecting growth and yield of groundnut in semi-arid regions such as the Sudan savanna is the availability of moisture during the cropping seasons. Among other agronomic factors low yielding varieties are the major constraints in groundnut production and quality (Asofo-Adjei *et al.*, 1998). In an experiment with two cultivars (Florunner, Pronto), Auma (1988) observed that the CV. Florunner had higher crop growth rate, pod production rate and dry matter partitioning than CV. Pronto (Anon, 2002). The difference in yield and yield attributes of groundnut were associated with differences in their genetic composition. Tanimu and Ado (1995) observed genotypic differences among varieties of groundnut as regards their response to variation in the environment. They therefore, concluded that it could be possible to select specific groundnut genotypes for specific environments. Earlier studies by Tanimu and Ado (1982) show that SAMNUT 12 produced significantly more pod yield than SAMNUT 18. In an irrigation trial to evaluate the performance of groundnut varieties under different basin size and plant population in Kadawa, Mukhtar (2009) found significant differences in pod yield among the three varieties evaluated (SAMNUT 23, SAMNUT 21, SAMNUT 11). Similarly, Bala *et al.* (2011) reported that higher pod yield in some groundnut resulted from higher number of pods plant^{-1} and shelling percentage. Stephen (2009) also reported differences in the performance of four varieties of groundnut in Ghana and concluded that the large-seeded varieties outperformed the small-seeded are in both the wet and dry seasons. At Samaru and Kadawa, Ibrahim (2015) reported that SAMNUT 11 had robust growth in both locations and seasons compared to other varieties, while SAMNUT 23 had erect bunch growth habit and flowered earlier than the other varieties. The high CGR recorded from SAMNUT 23 was attributed to early maturity. However, heavy branching in SAMNUT 11 gave it some advantages for weed suppression as evident by low weed cover score and weed control efficiency. In addition, SAMNUT 23 is late-maturing than SAMNUT 24 and earlier than SAMNUT 22, and therefore, adapted better to the northern Guinea savanna ecology where the rainfall is higher than in the Sahel zone (Chandraskaran *et al*., 2007).

2.2 Effect of Groundnut Varieties on Weeds

The variations observed among some groundnut varieties, as related to the heavy branching in SAMNUT -11, gave it some advantages for weed suppression as reflected in the low weed cover score and weed control efficiency (Ibrahim, 2015). This is in line with the findings of Haruna *et al.* (2019) who revealed that Bambara groundnut landrace with white coat and brown strip had the least injury score compared to the landrace with white coat white eye and white coat and black strip. The authors attributed the variation to the ability of bambara groundnut variety to compete and suppress weeds judging from the lower weed dry weight and weed cover score.

Groundnut varieties are susceptible to weed infestation. The spreading type offers a measure of competition against weeds after they completely cover the ground, but weeds that are able to grow above the canopy cover cause serious competition in the crop.

In a research work, Ibrahim (2015) indicated that SAMNUT-11 had significantly higher crop vigour score at 9 WAS than SAMNUT-22 and SAMNUT-23. Also, Jibrin (2015) reported that SAMNUT-24 had significantly lower weed cover score than KAMPALA variety at 6 WAS at Bayero University Kano (BUK) and at 9 WAS at Minjibir, both in Sudan savanna of Nigeria.

Genetic differences have been reported among peanut genotypes in tolerance to weed interference (Agostinho *et al.,* 2006; Hiremath *et al.,* 1997) and ability to suppress weed growth (Fiebig *et al.,* 1991). Crop height is beneficial characteristic for weed competition (Jannink *et al.,* 2000). Weeds that are not controlled early in the season can often grow taller than peanut, and can quickly overwhelm peanut even if differences in some morphological characteristics would be advantageous. Spanish and Valencia market-type peanut cultivar tend to have a more erect growth habit than virginia market types (Gregory *et al.,* 1951) and may compete more effectively with weeds. Hiremath *et al.* (1997) reported differences in cultivar tolerance to weed competition when comparing a Virginia market-type cultivar with Spanish and Valencia market-type cultivars.

Feakin (1973) stated that erect peanut cultivars are more tolerant to competition with weeds than the runner cultivars, probably due to formation of a compact above-ground mass, with greater shading between the lines.

2.3 Effect of Weed Control Methods on Growth and Yield of Groundnut

Several studies have shown that the productivity of groundnut is reduced considerably when weed competition occurs during the early growth stage of the crop. Rao (2004) revealed that the critical period of weed competition in groundnut was between 2 and 8 WAS. Yield components affected by weed competition are number of pods plant^{-1}, number of filled pods and means of kernel weight. Generally, the reduction in number of pods plant^{-1} by weed interference is directly related to the adverse effect of uncontrolled weed growth in groundnut. The slow early growth of groundnut makes the crop very susceptible to early weed interference. In general, weed competition in groundnut is more severe for the first six weeks from sowing. Rao (2004) reported 25 - 75% yield reduction in groundnut due to weed competition in India. In Ghana and Nigeria, 54% and 60% yield losses respectively, have been reported in groundnut (Akobundu, 1987). The author further attributed poor yield of groundnut in Africa to weed infestation. Uncontrolled weed growth has been reported to cause yield reduction of 50-80 percent in groundnut (Paulo *et al.,* 2001).

Chemical weed control has generally been superior to hand weeding but crop yields have been identical. For example, weed control with alachlor and fluorodifen was reported to be superior to hoe weeding (Anon., 1994). Oxyflorfen at 0.15 - 0.25 kg a.i ha^{-1} applied pre-emergence, fluchloralin at 1.0 kg a.i. ha^{-1} applied pre-plant incorporated or pendimethalin at 0.75 - 1.5 kg a.i ha^{-1} applied pre-emergence or imazethapyr at 0.1- 0.15 kg a.i ha^{-1} as early post- emergence were all effective in weed control (Anon., 1994).

Pre-emergence application of pendimethalin or metolachlor at the rate of 0.75 kg a.i. ha^{-1} or alachlor at 1.0 kg a.i. ha^{-1} or pre-plant incorporation of fluchloralin at of 0.75 kg a.i. ha^{-1} controlled weeds effectively (Rao, 2004). Post- emergence spray of quizalofop ethyl (5 E.C.) at 0.05 kg a.i. ha^{-1} or fluazifop-p-butyl (28 E.C.) at 0.25 kg a.i. ha^{-1} at 20 days after sowing (DAS) controlled later flush of weeds (Rao, 2004). Jhala *et al.* (2010) studied the effect of weed management practices and *rhizobium* inoculation on growth and yield of groundnut. They observed that minimum weed dry matter accumulation (70 kg ha^{-1}) with higher weed control efficiency (90.70%) was recorded under an integrated method, i.e. pendimethalin at 1.0 kg a.i. ha^{-1} + hand weeding at 30 DAS, which also resulted in maximum pod yield of 1,773.50 kg a.i. ha^{-1}. This treatment was comparable to fluchloralin applied at 1.0 kg ha^{-1} combined with hoe weeding at 30 DAS. Weedy conditions in the unweeded control treatment reduced pod yield by 29.90 - 35.95 % of that under the integrated method.

According to Akobundu (1987) two hoe weeding at 3 and 6 WAS were necessary for most legumes but groundnut may require additional weeding depending on location and because of its inability to develop canopy cover as fast as the other legumes. Weeding enable crop plants to have more resources for growth (Mubarak, 2004). Yadava and Kaura (2007) reported that weed control in groundnut led to increased number of branches plant^{-1} as compared to non-weeded plants. Generally, increase in weeding regime (manual or chemical) led to increased leaf area index, which is due to the absence of competition with weeds. Reduced competition and increased availability of resources like nutrients, soil moisture and light enhanced higher leaf area development. Effectiveness of weed control is largely dependent on the prevalent weed species, its life cycle and method of propagation. According to Rao (2004) since mechanical or cultural method alone does not ensure weed free condition, the use of herbicides in combination with cultural methods may be adopted. Furthermore, in areas where agricultural labour is scarce and costly, herbicides may be used as pre- and post-emergence application to control weeds.

One theory for reduced weed growth in narrow rows is quicker row closure, which reduces light penetration to the weeds emerging below the crop canopy (Alford *et al.,* 2004). Jat *et al*. (2011) reported that a good crop cover arising from the right inter- row (30 cm) spacing in the bunch-type groundnut and 45 cm in the spreading type and intra-row (10 cm) spacing will smother the growth of the weeds. Singh and Bajpai (1991) reported that large leaf area and better smothering effect of crop prevent the weeds from utilizing sufficient resources such as light, moisture and nutrients resulting in lesser dry weight of weeds. The weed population decreases with narrowing the row spacing and pairing of rows (30 – 60 – 30 cm) could decrease dry matter of weeds by 26.7%, compared with single-row planting (Devi Dayal *et al.,* 1994). Senthil Kumar (2009) reported that maintenance of a planting density of 500,000 plants ha^{-1} effectively reduced the weed density and weed dry weight, thereby producing higher weed control efficiency, however, the pod and kernel yields were significantly higher with 330,000 plants ha^{-1}. In a study conducted by El Naim *et al.*(2010)

on the influence of plant spacing and weeds on growth and yield of peanut (*Arachis hypogaea* L.) under rain-fed conditions in Sudan, the results revealed that the intra-row spacing of 10 cm and weeding twice enhanced groundnut production.

During the last decade, many industries have developed a variety of colored plastic films (polythene) for mulching, which have additional benefits related to altered quantity and quality of reflected light into the plant canopy (Andino and Motsenbocker, 2004) Inaddition, they have the effect of regulating the environment, suppressing weeds, controlling crop growth and pests and diseases (Bond and Grundy 2001, Mahajan *et al.,* 2007). In earlier studies, Orzolek *et al.* (1993) observed that the use of polythene mulch in the field increased soil temperature especially in early spring, reduced weed problems, increased moisture conservation, reduction in certain insect pests, higher crop yield and more efficient use of soil nutrients. Hu *et al.* (1995) recorded earlier seedling emergence, improved crop growth and nodule development in groundnut. Also Proline content in the groundnut was significantly enhanced on plots mulched with polythene sheets (Mahalle *et al*., 2002). Ramakrishna *et al.* (2006) reported that polythene mulched plots produced the highest yields compared to the unmulched plots in groundnut. Daisley *et al.* (1988) and Ossom *et al.* (2001) recorded significant differences in weed control between mulched and unmulched plots of eggplant, cowpea and sweet potato. In an experiment on the effect of black polythene film mulch on the growth and yield character of groundnut, Cheong *et al.* (1995) reported highly positive correlation of proportion of sound seeds, 100- seed weight and shelling ratio with seed yield of groundnut. In India, Subrahmaniyan *et al*. (2002) reported reduced weed incidence and dry matter production with higher number of pods plant^{-1}, pod yield and shelling percentage with the use of polythene film mulch, compared to non- mulched plots.

2.4 Effect of Weed Control Methods on Weed

Weed species respond differently to various weed control methods and agronomic maneover adopted by farmers suitable to there agroecology and little resources at their disporsal. This is line with the findings of Kim *et al.* (1983) who reported that variation in relative abundance of weed species encountered is governed by many factors such as soil structure, pH, nutrients and moisture status, associated crops, weed control measures and field history in local geographical variation.

In a research work on Bambara groundnut landraces conducted by Haruna *et al.* (2019) weeding at 3 WAS and at 3 and 6 WAS significantly recorded the lowest weed cover score than the other treatments and weedy check produced the highest weed cover score which was statistically comparable to fluazifop-p- butyl at 1.0 kg a.i ha^{-1}. This is in conformity with the experimental results by Rilwanu (2019) who reported that two hoe weeding at 3 and 6 WAS significantly gave low weed cover score and weed dry weight on groundnut. This could be due to the fact that hoe weeding, if done properly, does not spare any weed.

Olayinka and Etejere (2016) in a study on weed management in groundnut in 2010/2011 cropping seasons reported highest weed densities of 56.20 and 69.30 n/m^2, respectively from weedy check and followed in decreasing magnitude by those of sole rice straw mulch and pendimethalin at 1.5 l ha^{-1}. The weed free check had the lowest weed density while other weed control methods such as rice straw mulch + one hand weeding at 6 weeks after planting (WAP), two hand weedings at 3 and 6 WAP and pendimethalin at 1.5 l ha^{-1} + one hand weeding at 6 WAP had weed densities that were lower compared to the sole rice straw and pendimethalin at 1.5 l ha^{-1}.

Variations in weed cover score and weed dry weight was not significant at on all the varieties used. However, weedy check significantly and consistently resulted in higher values for the weed parameters while black polythene mulch recorded the least values for the aforementioned weed parameters which is comparable to pendimethalin at 1.5 kg a.i. ha^{-1} fb. Fluazifop-p- butyl at 1.0 kg a.i. ha^{-1} at both parameters and hoe weeding at 3 and 6 WAS at parameter weed dry weight at 12 WAS only (Jibrin *et al*., 2021).

In a research work conducted by Ibrahim (2015) on groundnut who reported that effect of weed control methods on weed control efficiency indicated that two hoe weeding resulted in significantly highest weed control efficiency which was followed by the application of 0.62 kg a.i. ha^{-1}, 0.108 kg a.i. ha^{-1} and 0.054 kg a.i. ha^{-1} Haloxyfop- R- Methyl ester respectively.

2.5 Effect of Time of Phosphorus Application on Growth and Yield of Groundnut

Phosphorus is the second major essential nutrient element for crop growth and good quality yield. Navnitkumar *et al.* (2012) reported that p is an important nutrient for all crops in general, and legumes in particular.

Phosphorus is one of the basic nutrient elements required by the groundnut plant during its growing period. During germination, P is converted to a form in which it can be translocated and becomes a part of new protein formed during growth. About 0.2 percent of the total dry weight of a plant is said made up of P (Ali and Mowafy, 2006).

Ayodele and Oso (2014) found that when P was applied at planting it enhanced early vegetative growth in terms of plant height, number of leaves and leaf area per plant. The control treatment gave the least values of all this growth parameter which did not differ significantly from withholding P fertilizer application until 3 and 5 WAS. Likewise, grain yield and yield components, namely; number of pods $plant^{-1}$, average pod length, number of seeds pod^{-1} and 100-seed weight were best with P applied at planting, application at 3 and 5 weeks after planting (WAP) did not differ significantly while the control treatment which gave least values. The control treatment gave lower index leaf, N, K, Ca and Mg contents, whereas P application increased P by 68 – 78% with the highest value obtained when P fertilizer was applied at planting (Ayodele and Oso, 2014).

Kebba (2015) reported that stem girth was greatest when P was applied at the time of planting groundnuts, and this was significantly higher than when applied at 1, 2 and 3 WAP.

At 60 WAP values for plant height were highest when the P fertilizer was applied at planting time, which was significantly higher than when the fertilizer was applied at 2 and 3 WAP. Differences between applying fertilizer at planting time and 1 WAP were not significant ($P \leq 0.05$).

Ramozemana (1999) reported that time of P application had no effect on number of pods but heavier pod weight was recorded for the control and where P was applied at 4 WAS. The average pod dry weight plant^{-1} were 0.5 and 1.0 g for the control and P application at 4 WAS, respectively, and 4.0 g for P application at sowing. This indicates that under P stress, the aerial plant parts did not supply sufficient assimilates for pod filling. Reducing early crop growth apparently has serious consequences for pod filling, and indicates the importance of a “starter P” on production of bambara groundnut and that a poor start cannot be made good by a later P application.

A study conducted by Ikombo *et al.* (1993) on the effect of rate and time of P application on seed yield of cowpea, revealed that among the top-dressed treatments the best seed yield (68% of maximum) was achieved with 70 kg P ha^{-1} applied at 14 or 21 days after sowing. Similarly, Ramozemana (1999) reported that plants supplied with extra mineral P during the initial stage (from sowing to 2 WAS) took up much more P (50 – 70 %) than unfertilized plants or plant receiving mineral P at 4 WAS.

Jones and Jacobsen (2009) reported that timing fertilization with peak nutrient uptake demands is essential for optimizing both yield and quality. In general, nutrient uptake rate are highest from early to mid-growing season, hence fertilization near the time of seeding is generally very effective. The authors recommended that P should be applied immediately before or at planting due to its immobility in soil.

2.6 Effect of Time of Phosphorus (P) Application on Weed Growth

The time of fertilizer application also influences weed species and their distribution patterns (Angonin *et al*., 1996). Fertilizer should be applied at proper time(s) so that weed infestation and proliferation can be checked to get maximum production from crop plants by optimizing the use of nutrients (Moody, 1977). Furthermore, varying fertilizer application time may reduce nutrient uptake by weeds as improper time might impose stressful environmental stress to weeds irrespective of crop stand establishment (Ahmad and Moody, 1981). This report was in agreement with observations of Evans *et al*. (2003) that time of fertilizer application can start or end weed competition, with crops if fertilizer is applied at early crop growth season; weeds may be controlled to a substantial level.

DiTomaso (1995) suggested that manipulating fertilization strategies reduces weed interference in crops. Varying fertilizer doses (Cathcart and Swanton, 2003), application timings (Blackshaw *et al*., 2004) and application methods (Mesbah and Miller, 1999) can modify weed-crop competition.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted in 2018 and 2019 wet seasons at the Teaching and Research Farms of Samaru College of Agriculture, Ahmadu Bello University, (ABU) Zaria, Kaduna State (11° $11^{'}$ N, 07° $38^{'}$ E; 686 m above sea level) located in the northern Guinea Savanna agro ecological zone of Nigeria, and Agricultural Research Station, Minjibir, Institute for Agricultural Research (IAR) Kano State (11^{0} $50^{'}$ N, 08^{0} $36^{'}$ E and 458 m above sea level) in Sudan savannah ecological zone of Nigeria.

3.2 Soil Analysis

Soil samples were taken randomly from 10 points at the depth of 0 – 30 cm from the experimental sites before establishing each trial. A tubular auger (10 cm diameter) was used to collect the soil samples. The soil samples were bulked; thoroughly mixed, air-dried, sieved using a 2-mm mesh and a composite sample was taken and analyzed to determine the physical and chemical properties using standard procedures as described by Black (1965). The soil particle size analysis was carried out by the hydrometer method (Day, 1965) and the textural class was determined using the textural triangle (USDA, 1960). Soil pH was determined using pH meter (Black, 1965). Total nitrogen was determined by macro-Kjeldahl digestion method (Bremner, 1965). Walkley and Black (1934) methods was used to determined organic carbon. Available P was extracted by Bray No. 1 method (Bray and Kurtz, 1945). Exchangeable bases were determined in neutral NH_4OAc extract (Black, 1968) by atomic absorption spectrophotometry for calcium and potassium and cation exchange capacity (CEC) was estimated by summation of Ca and K contents. The results of these analyses are shown in Table 1.

3.3 Meteorological Data

Information on the maximum and minimum temperature, relative humidity and rainfall for the growing seasons in the study areas was collected from the meteorological stations of Samaru College of Agriculture and Agricultural Research Station, Minjibir. The data collected are shown in Appendices I and II, respectively.

3.4 Treatments and Experimental Design

The treatments consisted of three groundnut varieties (SAMNUT-22; SAMNUT-23; SAMNUT-24), five weed control methods (weedy check; black polythene mulch; pendimethalin at 1.5 kg a.i. ha^{-1} as pre- emergence herbicide followed by (fb) fluazifop-p-butyl at 1.0 kg a.i ha^{-1} applied at 3 WAS; intra-row spacing at 10 cm; hoe weeding at 3 and 6 WAS), and two times of phosphorus fertilizer application (2 weeks before sowing; at sowing). The treatments were laid out in a split plot design with a factorial combination of weed control strategies and time of phosphorus fertilizer application in the main plot, while groundnut variety was allocated to the sub-plot. Three replications were used.

3.5 Test crop

Groundnut varieties SAMNUT 22, SAMNUT 23 and SAMNUT 24 were obtained from the Seed Unit of IAR, ABU, Zaria and the test crop descriptions are given (Anon.,2021);

3.5.1 SAMNUT-22

Groundnut variety M572.801 was released as SAMNUT-22 in the year 2001 by IAR, Ahmadu Bello University, Zaria. SAMNUT-22 is a medium-maturing variety (115-120 days), semi-erect in growth habit and has kernel oil content of 48%. It has a pod yield potential of 2.0 – 2.5 t ha^{-1} and haulm yield potential of 4.0 – 5.0 t ha^{-1}. It is tolerant to early and late leaf spot and rust. The kernel is large seeded and red in colour. SAMNUT-22 is well adapted to the northern Guinea savanna.

3.5.2 SAMNUT-23

Groundnut variety ICGV-15 96894, released as SAMNUT-23 in the year 2001 by IAR, Ahmadu Bello University, Zaria. SAMNUT-23 is an early-maturing variety (90-100 days), semi-erect and has kernel oil content of 56%. It has a pod yield potential of 2.0 – 2.5 t ha^{-1} and haulm yield of about 2.0 t ha^{-1}. The kernel colour is deep red and large in size. It is adapted to both the Sudan and Sahel savanna ecologies. This variety is similarly tolerant to early and late leaf spot and rust.

3.5.3 SAMNUT-24

Groundnut variety ICIAR19BT, released as SAMNUT-24, was jointly developed by scientists of ICRISAT and IAR, Ahmadu Bello University, Zaria, Nigeria. It is an extra-early maturing (80 - 90 days) variety with semi-erect growth habit. The estimated pod yield is about 2.0 – 2.5 t ha^{-1} and potential haulm yield is about 2.5 – 3.0 t ha^{-1}. The kernel colour is tan and has oil content of about 53 %. It is tolerant to rosette disease, early and late leaf spot. This particular variety has the ability to escape end of season drought due to early maturity. SAMNUT-24 adapts well to both the Sahel and Sudan savanna of Nigeria.

3.6 Cultural Practices

3.6.1 Land preparation

The land was harrowed twice to a fine tilth and ridged 75 cm between rows and then marked out into 90 plots with 1.5 m spacing between blocks and 0.5 m spacing between plots. The gross and net plot size were 18.0 m^2 (4.5 m x 4 m) and 6.0 m^2 (1.5 m x 4 m), respectively. However, there were six ridges in each gross plot and two ridges in net plot. The alley way between plots and replicates were 0.75 m and 1.5 m.

3.6.2 Fertilizer application

Phosphorus fertilizer as single super phosphate (18% P_2O_5) at the rate of 40 kg P_2O_5 ha^{-1} (17.44 kg P ha^{-1}) was applied as specified in section 3.4 above, using drilling method.

3.6.3 Seed Sowing

Sowing was done on 16th June, 2018 and 08th June, 2019 at Samaru, and on 23rd June, 2018 and 14th June, 2019 at Minjibir, respectively. The seeds were sown manually at the rate of three seeds per hill, at an inter-row and intra-row spacing of 75 cm x 20 cm at a soil depth of about 5 cm. The fully emerged plants were thinned to two plants $stand^{-1}$ at 2 WAS.

3.6.4 Weed control

Prior to land preparation glyphosate (Round – up 360 EC®) was applied at 2.5 kg a.i. ha^{-1} to the fallow vegetation. Thereafter, the weed control treatments were applied as specified in section 3.4 above after establishing the trials in both locations as described below:

Black polythene mulch

Black polythene sheet with a thickness of 7 µ was cut to the gross plot size 4.5 m x 4 m (6 ridges $plot^{-1}$) and perforated at 5 cm diameter at intervals of 20 cm after placing them on the assigned plots. Then, ball of earth were used to weight the sheet down at both sides of the furrow to prevent wind from blowing them off.

Herbicide application

Pendimethalin at 1.5 kg a.i. ha^{-1} was applied as pre emergence herbicide immediately after sowing on the assigned plots followed by fluazifop- p-butyl at 1.0 kg a.i. ha^{-1} three weeks later. All the herbicides were applied in the morning to prevent wind drift using a calibrated CP3 Knapsack sprayer to deliver a spray volume of 200 L ha^{-1}.

Intra-row spacing

The weed control treatments were applied to the assigned plots by sowing the groundnut seeds at closer spacing (75 cm x 10 cm).

Hoe-weeding

Hoe-weeding was carried out at 3 and 6 WAS for the specified treatments.

3.7 Harvesting and Processing

Harvesting was done at the time the crop attained physiological maturity i.e. when most leaves have turned brown and the inner ribs of the groundnut pod had a pronounced brown colour. The plants in the net plots were harvested by lifting out the whole plant, including the pods, with a hoe and handpicking the remaining pods from the soil. The pods were later detached from the haulms and allowed to dry under the sun. In harvesting, the different maturity period of the varieties were taken into consideration. The dried pods and haulms from each of the net plots were taken for the determination of groundnut yield parameters.

3.8 Data Collection

3.8.1 Weed Growth Parameters

Weed Floral Composition and Types

At 12 WAS the dominant weed species were collected from quadrat of 1m x 1 m, identified and described according to Akobundu and Agyakwa (1998). The occurrence of a particular weed species across experimental area and the level of occurrence were categorized and recorded based on the following: 1. +++ = High occurrence (60-90%) 2. ++ = Moderate occurrence (40- 59%) and 3. + = Low occurrence (10-39%).

Weed Dry Weight $g\ m^{-2}$

Weed samples were taken from 1m x 1 m quadrat at 3, 6, 9 and 12 WAS. Soil was removed completely from the samples before the samples were oven-dried at 70^{o} C to constant weight for dry matter determination using E2000 electronic mettler balance. The weights were recorded in $g\ m^{-2}$ for each plot.

Weed Control Efficiency (W.C.E.) (%)

Weed control efficiency was calculated on the basis of values of weed density weight at 12WAS. This was calculated using the formula as described by Das (2011).

$$W.C.E. = \frac{WDc - WD_T}{WDc} \; x \; 100$$

Where, WDc is the weed density (number/m^2) in control plot.

WD_T is the weed density (number/m^2) in treated plot.

Weed Cover Score

Weed cover score was assessed at 3, 6, 9 and 12 WAS by visual observation, using a scale of 1 – 9, where 1 represented no weed cover and 9 represented complete weed cover (Appendix V). The values obtained were recorded on per-plot basis.

3.8.2 Crop Growth Parameters

Groundnut/Crop *Stand Count*

The number of plants that emerged fully was counted in each net plot and recorded at 2 WAS.

Crop Vigour Score

Crop vigour score was assessed at 3, 6, 9 and 12 WAS by visual observation using a scale of 1 - 9 where 1 represented completely dead plant and 9 represented fully established plant (Appendix VI). Crop vigour was assessed based on; plant height, greenness of foliage, canopy spread, leaf size and stem thickness were used in assessing the crop vigour. The values obtained were recorded on per plot basis.

Crop Injury Score

Visual observation was used in assessing the crop injury in each plot using a scale of 1 – 9 at 3, 6, 9 and 12 WAS, where 1 represented the least injured plant, while 9 represented complete crop destruction (Appendix VII). Crop injury was assessed based on leaf necrosis, leaf burns and stunted growth of the crop. The value obtained for each plot was recorded.

Plant Height

Plants height was measured at 3, 6, 9 and 12 WAS using a metre ruler from the ground level to tip of the last fully expanded leaf of each of the five tagged plants in each net plot. The average was computed and recorded for each treatment was expressed in centimeter.

Canopy Spread

Canopy spread was measured from the five tagged plant by taking the diameter of the open canopy using a meter ruler at 3, 6, 9 and 12 WAS. The mean obtained were recorded on per-plot basis and expressed in centimeter.

Days to 50 percent Flowering

The number of days to 50% flowering was determined and recorded by counting the number of days from the date of sowing to when 50% of the plants in each net plot had flowered.

Nodule Counts

Nodules were sampled at 30 and 60 days after sowing. Five plant were randomly selected per plot, uprooted and the total number nodules counted. The mean number of nodules was recorded for each plot.

Crop Growth Rate

Crop growth rate (CGR) is the rate of dry matter production per unit ground area per unit time. CGR was calculated using the formula as suggested by Radford (1967):

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \quad (g\ m^{-2}\ wk^{1})$$

where: W_2 and W_1 are dry shoot weights taken at two respective time intervals: t_2 and t_1 respectively. The value was determined at 6, 9 and 12 WAS from the sampled plant stands after oven-drying at 70^0 c to a constant weight.

Relative Growth Rate (RGR)

Relative growth rate is the dry weight increment per unit plant weight per unit time. The value was determined at 6, 9 and 12 WAS from the sampled plant stands after oven-drying at

70° C to a constant weight, using the formula described by Radford (1967).

$$RGR = \frac{log_e W_2 - log_e W_1}{t_2 - t_1} \quad (g\ g^{-1}\ wk^{1})$$

where: W_2 and W_1 refer to total dry weight per plant at time t_2 and t_1 respectively.

Leaf Area Index (LAI)

Leaf area index is the area of ground covered per plant in a plants community. The leaf area of five sampled plants from the net plot was carefully measured using a Leaf Area Meter (Ceptometer Model Li-3100C). This was done at 6, 9 and 12 WAS and the values obtained were recorded.

3.8.3 Crop Yield Parameters

Pod Yield

Pod weight in kg plot^{-1} was determined from the weight of the total harvested pods in each net plot using E2000 electronic mettler balance, and the value estimated on per hectare basis.

Kernel Yield

The pods from the harvested from the two middle rows of the net plot were shelled and the weight of the kernels recorded on per-hectare basis, using the formula of Roland (2016).

$$\text{Kernel yield (kg ha}^{-1}\text{)} = \frac{\text{Kernel yield(kg)}}{\text{Harevest area (M}^2\text{)}}\ x\ 10{,}000\ m^2$$

where $10{,}000\ m^2$ represented one hectare of land.

One Hundred Kernel Weight

One hundred kernels were counted randomly from each of the harvested net plots, weighed and the values obtained were recorded in grams (g).

Haulm Yield

The haulm yield per net-plot weighed was extrapolated to kg ha^{-1}.

Harvest Index (H I)

This was obtained by taking the ratio of the seed yield to the total dry matter at harvest. It was obtained by using the formula (Mukhtar, 2009).

$$HI = \frac{\text{Grain yield from sample}}{\text{Total dry matter of sample}} X100.$$

Shelling Percentage

Shelling percentage is expressed as the percentage of kernels weight of unshelled pods. This was obtained using kernels and pods from each of the net plot. It was determined using the following formula (Mukhtar, 2009).

$$K = \frac{Kernels\ weight}{Pods\ weight}\ X\ 100$$

3.9 Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using the general linear model (GLM) of the Statistical Analysis System package (SAS, 2003) and Significant means were separated using the Duncan's Multiple Range Test using 5% level of significance (Duncan,1955). The relationship between weed, growth and yield parameters was determined from the matrix of correlation coefficients (Little and Hills, 1978).

3.10 Economic Analysis

The data on profitability of groundnut production were determined using Net Farm Income. The Net Farm Income is the difference between the total revenue and the total cost expressed as: NFI= TR-TC, where NFI= Net Farm Income, TR= Total revenue and TC= Total cost (Fabusoro and Agbonlahor, 2002; Umoh, 2006; Girei and Dire, 2013). The revenue from groundnut was obtained as a product of farm gate price of one kg of the crop and the yield measured in kg ha^{-1}. Farm-gate price of ₦ 266 kg $^{-1}$ was used in computing the revenue for pod yield at Samaru and Minjibir. ₦ 133 kg $^{-1}$ was the farm-gate price for haulm yield at both locations was taken as ₦ 133 kg $^{-1}$. The total revenue is the summation of the revenue from the pod and that of the haulm. Total variable cost is the summation of all the costs incurred for each treatment. Total cost is total variable cost and total fixed cost.

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Analysis

The results of the soil physical and chemical properties from the depth of 0 -30 cm at the two experimental sites (Samaru and Minjibir) in the 2018 and 2019 wet seasons are presented in Table 1. At Samaru, the textural class of the soils in both years was sandy loam with a neutral pH, low organic carbon, moderate total nitrogen, moderate in available phosphorus, calcium, magnesium, potassium, sodium and Cation Exchange Capacity.

Similarly, in both years the soil textural class at Minjibir was a sandy loam with neutral pH, low organic carbon, but moderately high total nitrogen and moderate available phosphorus, calcium However, the soil at Minjibir had low magnesium, potassium and sodium contents. But moderate in Cation Exchange Capacity.

4.2 Weed Floral Composition and Types

The predominant weed species found in Samaru and Minjibir location in 2018 and 2019 respectively were identified and classified as grasses, broadleaves and sedges. Table 2 shows weed floral composition and level of weed infestation at 12 weeks after sowing (WAS) during the 2018 and 2019 wet season at Samaru. The results revealed that there were slightly more broadleaf weeds in the experimental site than grass and sedge weeds in both years. In 2018, *O. herbacea* recorded highest level of infestation among the identified grasses while the remaining of the grass family members (*D. aegyptium, E. tremula, A. tectorum, C. dactylon, D. gayana and C. pilosa)* recorded low infestation in the experimental site. In the second year, all the grasses found recorded low infestation and this include; *O. herbacea, D. gayana, C. pilosa, B. lata, P. conjugatum and E. indica.*

Table 1: Physical and chemical properties of soils taken from 0 - 30 cm depth at Samaru and Minjibir experimental site in 2018 and 2019.

	Samaru		Minjibir	
Soil characteristics	**2018**	**2019**	**2018**	**2019**
Particle size distribution (g kg^{-1})				
Sand	54	58	60	85.3
Silt	36	32	24	6.3
Clay	10	10	16	8.4
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Chemical composition				
pH in H_2O (1:2. 5)	6.72	6.92	6.95	6.50
Organic carbon (g kg^{-1})	3.17	2.80	7.50	5.12
Total Nitrogen (g kg^{-1})	3.45	3.25	4.20	3.13
Available Phosphorus (mg kg^{-1})	8.64	6.64	15.85	15.73
Exchangeable bases (c mol kg^{-1})				
Calcium (Ca)	4.37	3.42	3.82	2.36
Magnesium (Mg)	0.53	0.48	0.34	0.22
Potassium (K)	0.19	0.15	0.16	0.13
Sodium (Na)	0.15	0.13	0.12	0.10
CEC (c mol kg^{-1})	6.1	5.9	5.2	4.9

Source: Soil Science Laboratory, Ahmadu Bello University, Zaria (2019).

Table 2: Weed Floral Composition and level of Infestation during the 2018 and 2019 wet seasons at Samaru.

Weed composition	Level of Infestation 2018	2019
Grasses		
Andropogon tectorum Schum and Thonn	+	_
Brachiaria lata (Schumach) C.E.	_	+
Chloris pilosa Schumach	+	+
Cynodon dactylon (Linn) Pers.	+	_
Dactyloctenium aegyptium (Linn) P. Beauv	+	_
Digitaria gayana (kunth) Stapf ex. Chav.	+	+
Eleusine indica Gaertn.	_	+
Eragrostis tremula Hochst ex. Steud	+	_
Oldenlandia herbacea (Linn) Roxb	+++	+
Paspalum conjugatum Berg.	_	+
Broadleaves		
Acanthospermum hispidum D.C.	+	+
Ageratum conyzoides Linn.	++	+++
Alternanthera sessilis (Linn) DC	_	+
Hyptis lanceolata Poir	++	++
Indigofera hirsuta Linn. var *hirsuta*	+	_
Ipomoea triloba Linn (=l webbiccyha)	+	_
Ludwigia abyssinica A. Rich (=Jussiaca abyssinica [A Rich] Dendy and Bienan)	+++	_
Spermacoce verticillata Linn.	+	_
Tridax procumbens Linn	+	+
Vernonia cinerea (Linn) Less	+++	+
Zornia latifolia SM	+	+
Sedges		
Cyperus difformis Linn	-	+
Cyperus esculentus Linn	++	+
Cyperus haspan Linn	+	_
Cyperus iria Linn	+	+
Cyperus rotundus Linn	+	_
Kyllinga bulbosa Beauv.	_	+
Kyllinga squamulata Thonn ex. Vahl	+	+
Leucas martinicensis (Jacq) Aitf	++	_
Mariscus longibracteatus Cherm (=*Cyperus longibrateatus* Cherm)	+	_
Spider worts		
Commelina benghalensis L.	-	++
Commelina diffusa Burm. F. Subsp. Diffusa J.K. Morton (=*C. nudiflora* L.)	+	+

+++ = High infestation (60 – 90%) ++ = Moderate infestation (40 – 59%), + = Low infestation (10 - 39%), - = No infestation.

In the category of broadleaves in 2018, *V. cinerea* and *L. abyssinica* recorded high infestation, while that of *H. lanceolata* and *A. conyzoides* were moderate infestation and the remaining broadleaves (*T. procumbens*, *I. triloba* (=l webbiccyha), *Z. latifolia*, *S. verticillata*, and *I. hirsuta* .var hissuta) encountered in the field had low infestation of the crops . In 2019, high infestation was recorded with *A. conyzoides* alone while *H. lanceolata* had moderate infestation and the other broadleaves *V. cinerea*, *T. procumbens*, *A. sessilis* and *Z. latifolia* in the field were of low infestation at Samaru. *L. martinicensis* (Jacq) and *C. esculentus* were the only sedges that had moderate infestation in 2018. While *C. iria* in both years and other members of the sedges had low infestation in the fields.

The variation in weed composition and their level of infestation at 12 WAS during 2018 and 2019 wet season at Minjibir is presented in Table 3. *O. herbacea* was the predominant grass in both years and recorded high infestation in the field. While *E. tremula* had moderate infestation only in 2019. Similarly, grass family member like *C. pilosa.* and *D. gayana* (Kunth) among others in 2018 and 2019 had low infestation in the study area. *H. lanceolata* in both year *Alternathera sessil* in 2018 and 2019 respectively all recorded high infestation in the study area. *S. obtusifolia* and *Z. latifolia* and the rest of the broad leaves in both years had low infestation. *C.esculentus* only is the most common weed and recorded moderate infestation in 2018 for sedges category. While the rest of the sedges family members in 2018 and 2019 had low infestation in the field.

Table 3: Weed Floral Composition and level of Infestation during the 2018 and 2019 wet seasons at Minjibir.

Weed composition	Level of Infestation 2018	2019
Grasses		
Androgon gayanus knuthvar. Gayanus	+	_
Brachiaria lata (Schumach)	_	+
Cenchrus biflorus Roxb.	_	+
Chloris pilosa .Schumach	+	+
Dactyloctenium aegyptium (Linn) P. Beauv	+	_
Digitaria gayana (Kunth) Stapf. Ex. A Chiov.	+	+
Eleusine indica .Gaertn	_	+
Eragrostis ciliaris (Linn) R. Br.	+	_
Eragrostis tremula Hochst. Ex. Steud	+	++
Paspalum conjugatum .Berg	+	_
Oldenlandia herbacea (Linn) Rioxb.	+++	+++
Broadleaves		
Acalypha fimbriata Schum and Thonn.	+	_
Ageratum conyzoides Linn	_	+
Alternanthera sessilis (Linn.) D.C.	+++	_
Hyptis lanceolata Poir	+++	+++
Senna obtusifolia	+	+
Spermacoce verticillata Linn.(=Borreria verticillata (L) G.F.W.Mey).	+	+
Tridax procumbens Linn	_	+
Zornia latifolia S.M.	+	+
Sedges		
Cyperus difformis Linn	+	+
Cyperus esculentus Linn	+	+
Cyperus haspan Linn	_	+
Cyperus rotundus .Linn	++	+
Kyllinga bulbosa .Beauv	+	_
Kyllinga squamulata Thonn. Ex. Vahl	+	+
Leucas martinocensis (Jacq) Ait	+	+
Mariscus longibracteatus Cherm (=cyperus longibracteatus)	+	+
Spider worts		
Commelina benghalensis L	_	++
Commelina diffusa .Burn F. Subsp. diffusa J.K. Morton	_	+++

+++ = High infestation (60-90%)   ++ = Moderate infestation (40- 59%)   + = Low infestation (10-39%), - = No Infestation

4.3 Weed Dry Weight (g)

4.3.1 Weed Dry Weight (3 WAS)

Table 4 shows the weed dry weight at 3 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. There were significant ($P \leq 0.05$) in weed dry weight was among the groundnut varieties only in 2019 and average in both locations. Plots grown to SAMNUT-24 recorded significantly the higher weed dry weight only when compared with SAMNUT-22 in both years and locations.

The effect of weed control method on weed dry weight was significant at 3 WAS. The weedy check recorded the highest value of weed dry weight compared to other weed control methods at Samaru in both years and the mean, but was at a *par* with 10 cm intra-row spacing in 2019. All the weed control methods in both years and mean except the use of black polythene mulch in 2019 and combined, gave similar weed dry weight. Black polythene mulch gave least weed dry weight in 2019 and mean. At Minjibir in both years and combined, the weedy check and 10 cm intra-row spacing gave similar but significantly higher weed dry weight than with all other weed control methods, except hoe weeding in 2018.
The use of black polythene mulch resulted in significantly lower weed dry weight in both years and combined but was at a *par* with hoe weeding in 2019. Weed dry weight in plots treated with pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p- butyl at 1.0 kg a.i. ha^{-1} was comparable only with hoe weeding at over time.

The effect of time of P application on weed dry weight was not significant in both locations, both years and mean. Similarly, no significant factor interactions were recorded.

Table 4: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Dry Weight at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Dry Weight at 3 WAS (g m^{-2})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	12.17	10.33b	11.22b	7.93	12.03b	9.98b
SAMNUT- 23	11.39	14.47ab	12.91ab	8.73	73.96ab	11.35ab
SAMNUT -24	16.97	16.75a	16.83a	10.36	15.45a	12.90a
S.E±	3.389	1.634	1.827	1.360	0.820	0.924
Weed control method (W)						
Weedy check	30.22a	21.98a	26.08a	10.11ab	24.33a	17.22a
Black polythene mulch	5.83b	0.00c	2.90c	1.22c	0.11d	0.66c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	6.74b	15.18b	10.94b	8.00b	15.05b	11.52b
Hoe-weeding at 3 and 6 WAS	14.79b	12.98b	13.86b	14.27a	0.11d	11.12b
Intra-row spacing (10 cm)	9.96b	19.09ab	14.49b	11.44ab	21.61a	16.52a
S.E.±	4.399	2.085	2.157	1.524	1.285	0.968
Time of phosphorus application (P)						
2 weeks before sowing	12.60	11.72	12.14	10.04	12.91	11.47
At sowing	14.42	15.97	15.17	7.97	16.72	11.34
S.E±	2.782	1.318	1.364	0.964	0.812	0.612
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.3.2 Weed Dry Weight (6 WAS)

Table 5 shows the weed dry weight at 6 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. There were significant differences in weed dry weight from plots grown to groundnut varieties with SAMNUT-23 having higher dry weight only when compared with SAMNUT-24 at Samaru over time across years and locations. However, at Minjibir in 2019 SAMNUT-22 had significantly higher weed dry weight than both SAMNUT-23 and SAMNUT-24 which were at a *par*.

The effect of weed control methods on weed dry weight was significant at 6 WAS. At Samaru in both years and mean, the weedy check gave significantly higher weed dry weight but this was at a *par* with values under application of pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop -p-butyl at 1.0 kg a.i. ha^{-1} and intra-row spacing of 10 cm in 2018. The use of black polythene mulch and hoe weeding at 3 and 6 WAS gave similar, and the least weed dry weight in 2018. In 2019 and the average over the years, the weedy check also gave the highest weed dry weight, while black polythene mulch had the least dry weight when compared to the remaining weed control methods. At Minjibir in 2018, the weedy check gave significantly higher weed dry weight than all others weed control methods which had similar weight. In 2019, application of pendimethalin at 1.5 kg a.i. ha-1 fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} resulted in significantly higher weed dry weight only when compared with hoe weeding at 3 and 6 WAS and use of black polythene mulch which recorded the least weed dry weight among the control methods.

Table 5: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Dry Weight at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Dry Weight at 6 WAS(g m^{-2})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	99.6a	223.78a	197.35ab	222.1ab	306.8a	264.4ab
SAMNUT- 23	99.8a	202.87a	377.48a	596.9a	204.5b	400.7a
SAMNUT -24	71.6b	138.96b	131.15b	178.7b	197.3b	187.9b
S.E$\pm$	4.805	14.433	66.360	132.17	50.96	70.47
Weed control method (W)						
Weedy check	147.7a	417.72a	699.7a	1040.8a	312.7ab	676.7a
Black polythene mulch	16.7b	0.83e	20.5b	90.2b	3.4c	46.8c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	131.9a	253.96b	224.4b	256.4b	472.4a	364.3b
Hoe-weeding at 3 and 6 WAS	24.3b	74.38d	70.4b	83.2b	107.3bc	95.2bc
Intra-row spacing (10 cm)	131.0a	195.81c	161.8b	192.3b	285.3ab	238.8bc
S.E.$\pm$	6.154	16.495	92.82	178.48	79.22	92.66
Time of phosphorus application (P)						
2 weeks before sowing	90.4	186.72	190.33	234.9	211.3	223.0
At sowing	90.2	190.36	280.33	430.3	261.1	345.6
S.E$\pm$	3.89	10.432	58.707	112.88	50.10	58.60
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The mean also showed that weedy check had heavier weed dry weight than in other control methods and use of black polythene recorded the least weed dry weight only among the control methods.

The effect of time of phosphorus application on weed dry weight at 6 WAS at both locations, years and mean was not significant. Also there was no significant effect of factor on the weed dry weight.

4.3.3 Weed Dry Weight (9 WAS)

Table 6 shows weed dry weight at 9 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. There were significant differences in weed dry weight among the groundnut varieties, except in 2019 at Minjibir. In 2018, in both locations and mean, SAMNUT-23 consistently had heavier weed dry weight when compared with other varieties in both locations and years. However, at Samaru in 2019, it had similar weed dry weight as the other varieties.

The effect of weed control method, on weed dry weight was significant. At Samaru in both years and mean, the weedy check had heavier dry weight compared with all other weed control methods. During the same sampled periods, the use of black polythene mulch gave the least weight which was similar to other weed control methods in 2018, to hoe weeding in 2019 and the mean.

In 2018 at Minjibir, weedy check and 10 cm intra-row spacing had significantly heavier weed dry weight compared with black polythene mulch which had the least weight.

Table 6: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Dry Weight at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Dry Weight at 9 WAS (g m^{-2})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	171.0b	266.92a	183.26a	270.9b	188.9	229.8b
SAMNUT- 23	552.1a	252.60a	176.18a	383.4a	227.2	305.3a
SAMNUT -24	123.4b	201.14b	136.36b	236.0b	181.4	208.7b
S.E±	132.25	15.316	7.787	15.75	16.40	11.15
Weed control method (W)						
Weedy check	981.7a	519.39a	333.54a	684.2a	339.1ab	511.6a
Black polythene mulch	40.1b	4.39d	10.53d	71.3c	6.3c	38.8d
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	194.8b	382.64b	256.81b	359.9b	377.0a	367.5b
Hoe-weeding at 3 and 6 WAS	66.4b	38.77d	31.55d	50.5b	25.3c	37.9d
Intra-row spacing (10 cm)	127.8b	255.91c	193.91c	319.8a	248.1b	283.9c
S.E.±	176.48	24.514	12.598	19.18	31.17	20.95
Time of phosphorus application (P)						
2 weeks before sowing	194.0	221.68	156.05	288.3	183.4	235.8
At sowing	370.3	258.76	174.49	305.3	214.9	260.1
S.E±	111.62	15.504	7.967	12.13	19.79	13.25
Interactions						
V x W	NS	NS	NS	*	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

However, in 2019 the use of pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} and weedy check (the mean inclusive) gave significantly higher values of weed dry weight as compared with the use of black polythene mulch and hoe weeding at 3 and 6 WAS which gave the least values for weed dry weight at Minjibir.

All factors interactions, except weed control method x groundnut variety in 2018 at Minjibir, did not significantly affect weed dry weight (Table 7). In the latter location and years.

Only the weed control method x groundnut variety interaction significantly affected. The weedy check with all the varieties had significantly higher weed dry weight compared with all other combinations. The use of black polythene mulch on all the groundnut varieties had lowest weed dry weight though statistically comparable to hoe weeding at 3 +6 WAS with all the groundnut varieties.

Interaction of SAMNUT-24 and SAMNUT-22 with pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} had lower weed dry weight but comparable to the use of intra-row spacing at 10 cm on the three groundnut varieties.

Table 7: Interaction Effect of Groundnut Variety and Weed Control Method on Weed Dry Weight at 9 WAS at Minjibir during 2018 wet season.

	Variety		
Weed control method	SAMNUT- 22	SAMNUT -23	SAMNUT - 24
Weedy check	626.5b	882.7a	543.5bc
Black Polythene mulch	74.4g	90.8g	48.8g
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	322.7ef	476.1cd	275.1f
Hoe-weeding at 3 and 6 WAS	39.5g	81.4g	30.8g
Intra-row spacing (10 cm)	291.4ef	386.2de	282.0f
SE±		73.0	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

4.3.4 Weed Dry Weight (12 WAS)

Table 8 shows weed dry weight at 12 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet season. SAMNUT-23 gave significantly higher dry weight in both years and mean at Samaru and 2018 at Minjibir and mean as compared to SAMNUT-22 and SAMNUT-24 respectively which significantly recorded the least weight.

The effect weed control method on weed dry weight was significant. At both locations in 2018, 2019 and mean, the weedy check and pendimethalin at 1.5 kg a.i. ha-1 fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} in 2019 at Minjibir significantly had heavier weed dry weight compared with black polythene mulch and hoe weeding at 3 and 6 WAS which were statistically at a *par* and had the least dry weight.

The effect of time of phosphorus application on weed dry weight was significant only in 2019 at Samaru at 12 WAS where application of P at 2 weeks before sowing gave higher weed dry weight compared with application at sowing.

The interaction between varieties and weed control methods on weed dry weight was significant at Samaru during 2018 and 2019 wet season combined as indicated in Table 9. The effect of weedy check in combination SAMNUT- 23 significantly gave the highest weed dry weight. The use of black polythene mulch on SAMNUT-24 significantly gave the lower weed dry weight though comparable to SAMNUT- 22 and SAMNUT-23. Also similar results were obtained when hoe weeding twice was used on all the groundnut varieties. Likewise, significant increase in weed dry weight was observed in all plots sown to groundnut varieties, with weedy check than the other weed control methods.

Table 8: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Dry Weight at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Dry Weight at 12 WAS (g m^{-2})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	208.3b	383.60b	295.96b	435.2ab	330.6	382.9ab
SAMNUT- 23	321.2a	551.85a	436.54a	510.8a	333.1	421.9a
SAMNUT -24	158.1c	302.28c	230.24c	396.0b	293.3	344.6b
S.E$\pm$	12.739	23.215	13.477	33.90	31.74	22.45
Weed control method (W)						
Weedy check	550.0a	1141.8a	845.92a	1053.5a	448.9a	751.2a
Black polythene mulch	40.9d	110.29c	75.58c	45.7c	219.3bc	132.5c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	303.8b	219.27c	261.53b	500.5b	468.4a	484.4b
Hoe-weeding at 3 and 6 WAS	44.8d	172.45c	108.43c	65.2c	109.9c	87.5c
Intra-row spacing (10 cm)	207.0c	419.20b	313.09b	571.5b	348.6b	460.0b
S.E.$\pm$	15.057	36.322	23.911	59.70	52.83	42.73
Time of phosphorus application (P)						
2 weeks before sowing	218.4	448.62a	333.52	485.2	308.8	397.0
At sowing	240.0	376.60b	308.30	409.4	329.2	369.3
S.E$\pm$	9.523	22.972	15.123	37.76	33.41	27.02
Interactions						
V x W	NS	NS	*	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

Table 9: Interaction Effect of Groundnut Variety and Weed Control Method on Average Weed Dry Weight at 12 WAS at Samaru.

Weed control methods	Varieties		
	SAMNUT-22	SAMNUT-23	SAMNUT-24
Weedy check	883.5b	1119.1a	535.1c
Black Polythene mulch	74.9hi	117.5ghi	34.3i
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	215.1fg	360.2de	209.3fg
Hoe-weeding at 3 and 6 WAS	84.8hi	155.8gh	84.7hi
Intra-row spacing (10 cm)	221.4fg	430.2cd	287.7ef
SE±		73.5	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

4.4 Weed Control Efficiency (WCE) (%)

The effect of weed management strategy and time of phosphorus application on WCE in plots grown to three groundnut varieties are presented in Table 10. Plots grown to SAMNUT-24 showed significantly higher WCE than SAMNUT-22 and SAMNUT-23 that had similar efficiency in 2018 and at both locations, In 2019 and the mean at Samaru, plots grown to SAMNUT-22 gave the highest WCE but this was similar to that of SAMNUT-24 only in the mean. On the other hand, SAMNUT-24 gave the lowest WCE in 2019. In 2019 at Minjibir and over time, SAMNUT-24 gave the highest WCE. However, SAMNUT-23 had the lowest WCE and this was comparable to that of SAMNUT-22.

The effect of weed control method on WCE was significant at all the sampling periods in both locations. In both years and over time at both locations, the use of black polythene mulch resulted in higher WCE except when compared with hoe weeding at 3 and 6 WAS in 2018 and average. Weedy check gave the least efficiency in both years and the mean. Pendimethalin at 1.5 kg a.i. ha-1 fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} and 10 cm intra-row spacing only at Minjibir in 2019 and the two-year average. However, the remaining of the weed control methods were at a *par* with the afore-mentioned weed control methods.

Table 10: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Control Efficiency at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Control Efficiency (%)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	59.88b	68.81a	64.34a	58.01b	59.29ab	58.65ab
SAMNUT- 23	57.53b	62.07b	59.80b	61.09b	36.51b	48.80b
SAMNUT -24	69.99a	55.19c	62.59ab	70.98a	82.66a	76.83a
S.E±	1.164	2.264	1.225	2.178	13.957	7.437
Weed control method (W)						
Weedy check	0.00d	0.00d	0.00c	0.00c	0.00b	0.00b
Black polythene mulch	98.20a	89.78a	93.99a	100.97a	52.59ab	76.78a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	51.57c	75.26b	63.41b	59.09b	90.90a	75.00a
Hoe-weeding at 3 and 6 WAS	98.80a	80.09b	89.45a	99.95a	74.48ab	87.22a
Intra-row spacing (10 cm)	63.76b	65.00c	64.38b	56.79b	79.47ab	68.13a
S.E.±	2.230	2.376	2.011	4.140	25.224	11.662
Time of phosphorus application (P)						
2 weeks before sowing	61.58	65.99a	63.78	62.58	58.30	60.44
At sowing	63.36	58.06b	60.71	64.14	60.68	62.41
S.E±	1.410	1.781	1.272	2.618	15.953	7.375
Interactions						
V x W	*	NS	NS	NS	NS	NS
V x P	NS	*	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

The effect of time of phosphorus application on weed control efficiency was only significant in 2019 at Samaru where P application at 2 weeks before sowing gave higher weed control efficiency than application at sowing.

Interaction effects of weed control method and variety on weed control efficiency of groundnut were significant at Samaru in 2018 as shown in Table 11. In each weed control method, significant increases were recorded only under black polythene mulch, pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} and hoe weeding at 3 and 6 WAS. SAMNUT-24 had significantly higher efficiency than the other two groundnut varieties. When the effect of weed control strategy on weed control efficiency was considered for each of the variety, it was found that use of black polythene mulch was most efficient in weed control though similar to that of hoe weeding at 3 and 6 WAS. Weedy check resulted in the least weed control efficiency, and this was followed by application of pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} in each variety.

Also, the interaction effect of variety and time of phosphorus application on weed control efficiency was significant in 2019 at Samaru as indicated in (Table 12). Plots supplied with phosphorus at 2 weeks before sowing all the varieties gave similar weed control efficiency. However, plots of all varieties supplied with phosphorus at sowing were significantly different in weed control efficiency. Only plots grown to SAMNUT-24, supplied of phosphorus at sowing had the lowest weed control efficiency.

Table 11: Interaction effect of Variety and Weed Control Method on Weed Control Efficiency of Groundnut at Samaru during 2018 wet season.

	Variety		
Weed control methods	SAMNUT -22	SAMNUT -23	SAMNUT-24
Weedy check	0.00e	0.00e	0.00e
Black Polythene mulch	90.96b	91.29b	112.36a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	51.13d	42.37d	61.23c
Hoe-weeding at 3 and 6 WAS	93.45b	89.87b	113.11a
Intra-row spacing (10 cm)	63.90c	64.15c	63.26c
SE±		6.72	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

Table 12: Interaction Effect of Variety and Time of Phosphorus Application on Weed Control Efficiency of Groundnut at Samaru during 2019 wet season.

	Variety		
Time of phosphorus application	SAMNUT- 22	SAMNUT -23	SAMNUT- 24
2 weeks before sowing	68.69a	64.12a	65.16a
At sowing	68.93a	60.03a	45.24b
SE±		12.6	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance

The application of P at sowing to SAMNUT-24 had lower value for weed control efficiency than that from 2 weeks before sowing groundnut varieties. The effect of time of P application on weed control efficiency was only significant in SAMNUT- 24 where done 2 weeks to sowing which resulted in higher weed control efficiency that of at sowing.

4.5 Weed Cover Score

4.5.1 Weed Cover Score (3 WAS)

The effect of weed control method and time of phosphorus application on weed cover score of groundnut varieties at 3 WAS are presented in Table 13. Differences in weed cover score were not significant in both locations and years except the average score at Minjibir, where SAMNUT-23 had comparable value with SAMNUT-22 but significantly higher than SAMNUT-24.

The effect of weed control on weed cover score was significant in both years at all locations. Weedy check resulted in the highest weed cover score in both years and locations but this was similar to hoe weeding at 3 and 6 WAS at Minjibir in 2018. Black polythene mulch gave the lowest weed cover score in 2019 and the average in both locations. The use of hoe weeding at 3 and 6 WAS, 10 cm intra-row spacing and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} gave similar weed cover score that was lower when than in the weedy check in both years, locations and the average.

The effect of time of phosphorus application on weed cover score at 3 WAS in both locations, years and the average was not significant. There were no significant factor interaction effects on weed cover score.

4.5.2 Weed Cover Score (6 WAS)

The effects of weed control method and time of phosphorus application on weed cover score of groundnut varieties at 6 WAS are presented in Table 14. Groundnut varieties exhibited

Table 13: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Cover Score at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Cover Score at 3 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	3.20	2.70	2.95	3.06	2.76	2.91ab
SAMNUT- 23	3.23	2.53	2.88	3.13	2.80	2.96a
SAMNUT -24	3.30	2.46	2.88	3.00	2.56	2.78b
S.E±	0.138	0.096	0.086	0.109	0.100	0.056
Weed control method (W)						
Weedy check	4.77a	3.77a	4.27a	3.778a	4.55a	4.16a
Black polythene mulch	2.27b	1.00c	1.63c	2.56b	1.388d	1.72d
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	2.50b	2.77b	2.63b	2.778b	2.66bc	2.47c
Hoe-weeding at 3 and 6 WAS	3.44b	2.50b	2.97b	4.389a	2.11c	3.25b
Intra-row spacing (10 cm)	3.22b	2.77b	3.00b	2.833b	2.83b	2.83bc
S.E.±	0.365	0.210	0.260	0.309	0.196	0.175
Time of phosphorus application (P)						
2 weeks before sowing	2.91	2.55	2.73	3.15	2.84	2.86
At sowing	3.57	2.57	3.07	2.97	2.57	2.91
S.E±	0.231	0.133	0.164	0.195	0.124	0.111
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 14: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Cover Score at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Cover Score at 6 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	3.70ab	3.50ab	3.60a	3.46a	3.50b	3.48b
SAMNUT- 23	3.96a	3.60a	3.78a	3.53a	3.73a	3.63a
SAMNUT -24	3.46b	3.33b	3.40b	3.36b	3.20c	3.28c
S.E±	0.113	0.066	0.069	0.050	0.063	0.043
Weed control method (W)						
Weedy check	6.11a	5.38a	5.75a	6.94a	5.16a	6.05a
Black polythene mulch	2.26d	2.00c	2.08c	2.00d	2.00c	2.00d
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	3.50c	4.00b	3.75b	2.61c	4,16b	3.38c
Hoe-weeding at 3 and 6 WAS	2.50d	2.00c	2.25c	2.000c	2.11c	2.05d
Intra-row spacing (10 cm)	4.27b	4.00b	4.13b	3.72b	3.94b	3.83b
S.E.±	0.143	0.191	0.151	0.110	0.101	0.100
Time of phosphorus application (P)						
2 weeks before sowing	3.24b	3.35	3.30b	3.31	3.44	3.37
At sowing	4.17a	3.60	3.88a	3.60	3.51	3.55
S.E±	0.202	0.087	0.095	0.129	0.064	0.063
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

significant differences in weed cover score. SAMNUT-23 consistently gave the higher weed cover score in both locations and years though at a *par* with SAMNUT-22, except in 2019 and the average at Minjibir. SAMNUT-24 recorded the least weed cover score in both locations, years and the average.

The effect of weed control on weed cover score was significant in both years at all locations. Weedy check gave the highest weed cover score in both years and locations, contrasting the least values under black polythene mulch and hoe weeding at 3 and 6 WAS. The use of 10 cm intra-row spacing and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} produced moderate weed cover score though statistically similar in both year , location and mean in most cases.

The effect of time of phosphorus application on weed cover score was significant only at Samaru in 2018 and mean. Time of Phosphorus application at sowing significantly resulted in higher weed cover score than P application at 2 weeks before sowing. The effects of factor interaction on weed cover score were not significant.

4.5.3 Weed Cover Score (9 WAS)

The effects of weed control method and time of phosphorus application on weed cover score of groundnut varieties at 9 WAS are presented in Table 15. Groundnut varieties exhibited significant differences in weed cover score. SAMNUT-23 consistently gave the higher weed cover score in both locations and years though at a *par* with SAMNUT-22, except in both years and the average at Samaru. SAMNUT-24 recorded the least weed cover score in all locations, years and the average, but statistically at a *par* with SAMNUT-22 in both years and the average at Samaru.

Table 15: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Cover Score at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Cover Score at 9 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	3.63b	3.80b	3.71b	3.76a	3.63a	3.70a
SAMNUT- 23	3.96a	4.26a	4.11a	3.83a	3.76a	3.80a
SAMNUT -24	3.53b	3.67b	3.60b	3.46b	3.43b	3.45b
S.E+	0.069	0.091	0.054	0.087	0.062	0.057
Weed control method (W)						
Weedy check	6.83a	6.50a	6.66a	6.833a	6.27a	6.55a
Black polythene mulch	2.11c	2.00c	2.05c	2.222c	2.00c	2.11c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	3.50b	4.61b	4.05b	3.722b	3.83b	3.77b
Hoe-weeding at 3 and 6 WAS	2.00c	2.05c	2.02c	1.778c	2.05c	1.91c
Intra-row spacing (10 cm)	4.11b	4.38b	4.25b	3.889b	3.88b	3.88b
S.E.+	0.359	0.138	0.183	0.323	0.202	0.207
Time of phosphorus application (P)						
2 weeks before sowing	3.35b	3.95	3.65	3.82	3.53	3.67
At sowing	4.06a	3.86	3.96	3.55	3.68	3.62
S.E+	0.227	0.087	0.116	0.204	0.128	0.131
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The effect of weed control on weed cover score was significant in both locations and years. Weedy check gave the highest weed cover score in both years and locations. Black polythene mulch and hoe weeding at 3 and 6 WAS had the least weed cover score in both locations and years. Pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, 10 cm intra-row spacing produced moderate weed cover score though at a *par* in both years , locations and mean.

The effect of time of phosphorus application on weed cover score was significant only at Samaru in 2018. Time of phosphorus application at sowing significantly resulted in higher weed cover score than P application at 2 weeks before sowing. The effects of factor interaction on weed cover score were not significant.

4.5.4 Weed Cover Score (12 WAS)

The effects of weed control method and time of phosphorus application on weed cover score of groundnut varieties at 12 WAS are presented in Table 16. The groundnut varieties exhibited significant differences in weed cover score. SAMNUT-23 consistently gave the higher weed cover score in both locations and years though at a *par* with SAMNUT-22, except in 2018 and the average at Samaru. SAMNUT-24 recorded the least weed cover score in all locations, years and the mean, but statistically at a *par* with SAMNUT-22 in both years and the mean at Minjibir and 2019 at Samaru.

The effect of weed control on weed cover score was significant in both locations and years. Weedy check gave the highest weed cover score in both years and locations though at a *par* with 10 cm intra-row spacing at the average of Samaru. Black polythene mulch in both years at Samaru and the average at Minjibir, hoe weeding at 3 and 6 WAS in 2018 at Samaru and the mean at Minjibir had the least weed cover score.

Table 16: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Weed Cover Score at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Weed Cover Score at 12 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	4.93b	4.46ab	4.70b	3.46a	4.00a	3.73a
SAMNUT- 23	5.33a	4.80a	5.06a	3.53a	4.13a	3.83a
SAMNUT -24	3.90c	4.26b	4.08c	2.46b	3.83b	3.15b
S.E±	0.107	0.132	0.080	0.063	0.054	0.043
Weed control method (W)						
Weedy check	7.61a	7.38a	7.50a	6.667a	6.50a	6.58a
Black polythene mulch	2.66d	2.05d	2.36c	1.833c	2.00c	1.91d
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	4.38c	5.27b	4.83b	2.167c	4.61b	3.38c
Hoe-weeding at 3 and 6 WAS	2.77d	3.00c	2.88c	1.667c	2.50c	2.08d
Intra-row spacing (10 cm)	6.16b	4.83b	7.50a	3.444b	4.33b	3.88b
S.E.±	0.373	0.186	0.225	0.204	0.209	0.151
Time of phosphorus application (P)						
2 weeks before sowing	4.33b	4.42	4.37b	3.11	3.77b	3.44
At sowing	5.11a	4.60	4.85a	3.20	4.20a	3.70
S.E±	0.236	0.117	0.142	0.129	0.132	0.095
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing gave similar weed cover score that was lower when compared with weedy check at both locations and years except for the mean at Samaru for 10 cm intra-row spacing.

The effect of time of phosphorus application on weed cover score was significant at Samaru in 2018, Minjibir in 2019 and the mean at Samaru. Time of Phosphorus application at sowing significantly resulted in higher weed cover score than P application at 2 weeks before sowing. The effects of factor interaction on weed cover score were not significant.

4.6 Groundnut / Crop Stand Count

Groundnut / crop stand count as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir in 2018 and 2019 are shown in Table 17. SAMNUT-24 significantly and consistently produced higher stand counts than SAMNUT-22 and SAMNUT-23 which had similar stand count in 2018, 2019 and the mean at Samaru and Minjibir.

The effect of weed control method on stand count was significant in both locations and years. At both locations and in both years, 10cm intra-row spacing significantly gave the highest stand count of groundnut plants compared to the other weed control methods used; however, stand count under black polythene mulch was comparable to that under 10 cm intra-row spacing in 2019 at Minjibir. Weedy check at Samaru in 2019, black polythene mulch in 2018 at Minjibir and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} mean at Minjibir produced the least stand counts.

The time of phosphorus application had no significant effect on stand count in both locations and year. Similarly, the effect of factor interaction on stand count was not significant.

Table 17: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Groundnut Crop/Stand Count at 2 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop/Stand Count					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	27.10b	30.73b	28.91b	29.10b	24.43b	26.76b
SAMNUT- 23	26.53b	30.76b	28.65b	28.50b	24.06b	26.28b
SAMNUT -24	35.53a	35.96a	35.75a	34.26a	28.33a	31.30a
S.E±	1.290	1.025	0.881	0.782	0.976	0.544
Weed control method (W)						
Weedy check	25.77b	26.44c	26.11b	30.278b	21.72cd	26.00bc
Black polythene mulch	28.22b	31.22b	29.72b	25.722c	28.88ab	27.30bc
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	28.11b	28.77bc	28.44b	30.444b	20.05d	25.25c
Hoe-weeding at 3 and 6 WAS	26.72b	28.38bc	27.55b	30.778b	25.61bc	28.19b
Intra-row spacing (10 cm)	39.77a	47.61a	43.69a	35.889a	31.77a	33.83a
S.E.±	1.934	1.250	1.398	1.158	1.473	0.711
Time of phosphorus application (P)						
2 weeks before sowing	29.46	32.66	30.88	30.289	26.84	28.56
At sowing	29.97	32.31	31.32	30.956	24.37	27.66
S.E±	1.223	0.732	0.884	0.732	0.931	0.449
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.7 Crop Vigour Score

4.7.1 Crop Vigour Score (3 WAS)

Table 18 shows the effect of weed control methods and time of phosphorus application on crop vigour score of groundnut varieties at 3 WAS. SAMNUT-24 showed better vigour when compared to other varieties except with SAMNUT-22 in 2019 at both locations. SAMNUT-23 had lower but similar vigour when compared with SAMNUT-22 in 2018 at both locations.

The effect of weed control method on crop vigour score was significant at both locations and in both years. Black polythene mulch significantly and consistently produced higher values of crop vigour score. Weedy check consistently produced the least vigorous crop in both years and locations. The use of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, hoe weeding at 3 and 6 WAS and 10cm intra-row spacing resulted in moderate crop vigour across locations and years.

The effect of time of phosphorus application on crop vigour score was significant only at Samaru in 2018. Application of phosphorus at 2 weeks before sowing groundnut resulted in higher crop vigour score than application at sowing. There was no significant factor interaction across locations and years.

Table 18: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Vigour Score at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Vigour Score at 3 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	5.46b	6.67a	6.06b	5.86b	6.86a	6.36b
SAMNUT- 23	5.20b	6.10b	5.65c	5.73b	6.20b	5.96c
SAMNUT -24	6.06a	7.00a	6.53a	6.56a	7.16a	6.86a
S.E$\pm$	0.190	0.120	0.117	0.144	0.119	0.086
Weed control method (W)						
Weedy check	4.27c	5.44d	4.86c	5.167c	5.33c	5.25c
Black polythene mulch	7.00a	8.00a	7.50a	7.667a	7.78a	7.72a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	5.94ab	6.00cd	5.97b	6.722ab	6.55b	6.63b
Hoe-weeding at 3 and 6 WAS	5.00bc	6.77b	5.88b	4.778c	7.11b	5.94bc
Intra-row spacing (10 cm)	5.66b	6.72bc	6.19b	5.944bc	6.94b	6.44b
S.E.$\pm$	0.404	0.246	0.289	0.441	0.208	0.257
Time of phosphorus application (P)						
2 weeks before sowing	6.04a	6.64	6.34	5.86	6.86	6.36
At sowing	5.11b	6.53	5.82	6.24	6.62	6.43
S.E$\pm$	0.255	0.156	0.183	0.279	0.131	0.163
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.7.2 Crop Vigour Score (6 WAS)

Table 19 shows the effect of weed control methods and time of phosphorus application on crop vigour score of groundnut varieties at 6 WAS. SAMNUT-24 showed better vigour when compared to other varieties except with SAMNUT-22 in 2018 at Samaru where it had similar vigour with SAMNUT-24. SAMNUT-23 had lower vigour only when compared with SAMNUT-22 at Samaru in both years and the mean at Minjibir.

The effect of weed control methods on crop vigour score was significant at both locations and in both years. Black polythene mulch consistently produced higher vigour score at both locations and years than other control methods, except when compared with hoe weeding at 3 and 6 WAS where the vigour was statistically similar. Weedy check consistently produced the least vigorous crop in both years and locations when compared to other control methods except at Samaru in 2018 where it had similar value with 10 cm intra-row spacing

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The effect of time of phosphorus application on crop vigour score was significant only at Samaru in both years. Application of phosphorus at 2 weeks before sowing groundnut gave higher crop vigour score than application at sowing. There was no significant interaction across locations and years.

Table 19: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Vigour Score at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Vigour Score at 6 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	6.03a	6.36b	6.20b	5.93b	6.10b	6.01b
SAMNUT- 23	5.56b	5.90c	5.73c	5.60b	5.09b	5.75c
SAMNUT -24	6.30a	6.73a	6.51a	6.93a	6.36a	6.65a
S.E$\pm$	0.153	0.103	0.084	0.146	0.078	0.080
Weed control method (W)						
Weedy check	4.66c	4.50c	4.58c	4.667c	3.22c	3.94c
Black polythene mulch	7.33a	7.61a	7.47a	7.333a	8.00a	7.66a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	5.72bc	6.22b	5.97b	5.944b	5.55b	5.75b
Hoe-weeding at 3 and 6 WAS	6.55ab	6.94ab	6.75ab	7.222a	7.88a	7.55a
Intra-row spacing (10 cm)	5.55bc	6.38b	5.97b	5.611b	5.94b	5.77b
S.E.$\pm$	0.389	0.279	0.251	0.255	0.226	0.140
Time of phosphorus application (P)						
2 weeks before sowing	6.51a	6.60a	6.55a	6.00	6.13	6.06
At sowing	5.42b	6.06b	5.74b	6.31	6.11	6.21
S.E$\pm$	0.246	0.177	0.158	0.161	0.143	0.088
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.7.3 Crop Vigour Score (9 WAS)

Table 20 shows the effect of weed control methods and time of phosphorus application on crop vigour score of groundnut varieties at 9 WAS. SAMNUT-24 showed better vigour when compared to other varieties except with SAMNUT-22 at Samaru in 2018 where it had similar vigour. SAMNUT-23 had lower vigour at both locations and years except for Samaru in 2018.

The effect of weed control methods on crop vigour score was significant at both locations and in both years. Black polythene mulch in both locations and years except for combined at Minjibir significantly produced higher vigour score though at a *par* with hoe weeding at 3 and 6 WAS in 2018 at Samaru and both years at Minjibir including the mean. Weedy check significantly produced the least vigorous crop in both years and locations. The use of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing produced moderate crop vigour score in both locations, years and the average.

The effect of time of phosphorus application on crop vigour score was significant at Samaru in 2018 and combined. Application of phosphorus 2 weeks before sowing groundnut resulted in higher crop vigour score than the time of phosphorus application at sowing. There was no significant interaction across locations and in both years and the mean.

Table 20: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Vigour Score at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Vigour Score at 9 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	6.06a	6.06b	6.06b	6.10b	5.66b	5.88b
SAMNUT- 23	4.90b	5.76c	5.33c	5.66c	5.13c	5.40c
SAMNUT -24	6.30a	6.66a	6.48a	6.83a	6.30a	6.56a
S.E±	0.145	0.090	0.087	0.126	0.084	0.081
Weed control method (W)						
Weedy check	3.38c	4.05d	3.72d	4.611b	2.88c	3.75c
Black polythene mulch	7.61a	8.00a	7.80a	7.278a	7.77a	7.52c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	5.66b	5.72c	5.69c	5.667b	5.22b	5.44b
Hoe-weeding at 3 and 6 WAS	6.94a	7.27b	7.11b	7.722a	7.16a	7.44a
Intra-row spacing (10 cm)	5.16b	5.77c	5.47c	5.722b	5.44b	5.58b
S.E.±	0.273	0.188	0.167	0.498	0.252	0.254
Time of phosphorus application (P)						
2 weeks before sowing	6.08a	6.28	6.18a	6.17	5.66	5.92
At sowing	5.42b	6.04	5.73b	6.22	5.73	5.97
S.E±	0.172	0.119	0.105	0.315	0.159	0.160
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.7.4 Crop Vigour Score (12 WAS)

Table 21 shows the effect of weed control methods and time of phosphorus application on crop vigour score of groundnut varieties at 12 WAS. SAMNUT-24 showed better vigour when compared to other varieties though at a *par* with SAMNUT-22 at Samaru in both years and 2019 at Minjibir. SAMNUT-23 had lower vigour at both locations, years and the average.

The effect weed control methods on crop vigour score were significant at both locations and in both years. With the exception of hoe weeding at 3 and 6 WAS at Minjibir in 2019 that produced moderates vigour score. Black polythene mulch and hoe weeding at 3 and 6 WAS in both locations and in both years had higher crop vigour score. Weedy check significantly produced the least crop vigour score in 2019 in both locations and the mean, except in 2018 in both locations where the value are at a *par* with the rest of the weed control methods.

The effect of time of phosphorus application on crop vigour score was significant at Minjibir in 2019 only. Application of phosphorus at 2 weeks before sowing groundnut resulted in higher crop vigour score than the time of phosphorus application at sowing. There was no significant factor interaction at both locations, years and the mean.

4.8 Crop Injury Score

4.8.1 Crop Injury Score (3 WAS)

Table 22 shows the crop injury score at 3 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons.

Table 21: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Vigour Score at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Vigour Score at 12 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	5.60a	5.53a	5.56a	5.40b	5.83a	5.61b
SAMNUT- 23	5.03b	4.56b	4.80b	5.60ab	5.40b	5.50b
SAMNUT -24	5.43ab	5.66a	5.55a	6.16a	6.10a	6.13a
S.E±	0.162	0.137	0.110	0.223	0.108	0.130
Weed control method (W)						
Weedy check	4.00b	2.94c	3.47c	4.667b	3.77d	4.22c
Black polythene mulch	6.83a	7.61a	7.22a	6.944a	8.00a	7.47a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	4.83b	4.33b	4.58b	5.500ab	4.88c	5.19b
Hoe-weeding at 3 and 6 WAS	6.61a	6.50a	6.55a	6.889a	7.38b	7.13a
Intra-row spacing (10 cm)	4.50b	4.88b	4.69b	4.611b	4.83c	4.72bc
S.E.±	0.430	0.394	0.300	0.492	0.181	0.234
Time of phosphorus application (P)						
2 weeks before sowing	5.73	5.31	5.52	5.48	6.04a	5.76
At sowing	4.97	5.20	5.08	5.95	5.51b	5.73
S.E±	0.272	0.249	0.189	0311	0.114	0.148
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 22: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Injury Score at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Injury Score at 3 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	3.50a	2.33b	2.91b	3.13a	2.13b	2.63b
SAMNUT- 23	3.83a	2.86a	3.35a	3.30a	2.86a	3.08a
SAMNUT -24	2.93b	2.00b	2.46c	2.50b	1.83b	2.16c
S.E±	0.196	0.123	0.121	0.147	0.123	0.087
Weed control method (W)						
Weedy check	4.72a	3.55a	4.13a	3.88a	3.67a	3.77a
Black polythene mulch	2.05c	1.00c	1.52c	1.33c	1.22c	1.27c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	3.00bc	3.00a	3.00b	2.33bc	2.50b	2.41b
Hoe-weeding at 3 and 6 WAS	4.00ab	2.16b	3.08b	4.27a	1.94b	3.11ab
Intra-row spacing (10 cm)	3.33b	2.27b	2.80b	3.05ab	2.05b	2.55b
S.E.±	0.405	0.236	0.282	0.440	0.201	0.264
Time of phosphorus application (P)						
2 weeks before sowing	2.95b	2.33	2.64b	3.15	2.17	2.66
At sowing	3.88a	2.46	3.17a	2.80	2.37	2.58
S.E±	0.256	0.149	0.178	0.280	0.127	0.167
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The effect of groundnut variety on crop injury score was significant at all locations in both years and the mean and SAMNUT-23 consistently had the most injured crop stand but similar to SAMNUT-22 in 2018 at both locations. SAMNUT-24 had the least injured crop stand at both locations and years but this was similar to SAMNUT-22 in 2019 at both locations.

The effect of weed control methods on crop injury score was significant at both locations and in both years. Weedy check consistently produced the most injured crop but this was similar to pendimethalin at 1.5 kg a.i ha^{-1} fb.fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Samaru in 2019 and hoe weeding at 3 and 6 WAS in both locations in 2018 and the mean at Minjibir. Black polythene mulch significantly gave the least injured plants across locations, years and over time. However, the remaining weed control methods are at a *par* and produced moderately injured crop at both locations and in both years.

The effect of time of phosphorus application on crop injury score was significant at Samaru in 2018 and over time. Application of phosphorus at sowing resulted in significantly higher crop injury than phosphorus application at 2 weeks before sowing groundnut. There was no significant effect of factor on crop injury score.

4.8.2 Crop Injury Score (6 WAS)

Table 23 shows the crop injury score at 6 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet seasons. The effect of groundnut variety on crop injury score was significant at all locations, both years and the mean. SAMNUT-23 consistently had the most injurious crop stand when compared to other varieties at Samaru in both years and the mean. However, SAMNUT 24 had lower injured crop stand only in 2019 and the mean. At Minjibir,

Table 23: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Injury Score at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Injury Score at 6 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	2.93b	2.63b	2.78b	3.10a	2.90a	3.00b
SAMNUT- 23	3.43a	3.06a	3.25a	3.40a	3.10a	3.25a
SAMNUT -24	2.70b	2.23c	2.46c	2.06b	2.63b	2.35c
S.E$\pm$	0.155	0.105	0.087	0.148	0.078	0.082
Weed control method (W)						
Weedy check	4.33a	4.50a	4.41a	4.389a	5.77a	5.08a
Black polythene mulch	1.66c	1.38c	1.52c	1.667c	1.00c	1.33c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	3.27ab	2.77b	3.02b	3.056b	3.44b	3.25b
Hoe-weeding at 3 and 6 WAS	2.38bc	2.05bc	2.22c	1.778c	1.11c	1.44c
Intra-row spacing (10 cm)	3.44ab	2.50b	2.97b	3.389b	3.05b	3.22b
S.E.$\pm$	0.382	0.273	0.244	0.258	0.226	0.134
Time of phosphorus application (P)						
2 weeks before sowing	2.48b	2.37b	2.43b	3.00	2.86	2.93
At sowing	3.55a	2.91a	3.23a	2.71	2.88	2.80
S.E$\pm$	0.241	0.173	0.154	0.163	0.143	0.085
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan’s Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

SAMNUT-23 had the higher injured crop stand only when compared to SAMNUT-24 at both mean.

The effect of weed control methods on crop injury score was significant at both locations and in both years. Weedy check consistently produced the most injurious crop stand but this was similar to pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing at Samaru in 2018. Black polythene mulch significantly gave the least injurious plants across the locations, years and over time though at a *par* with hoe weeding at 3 and 6 WAS. While pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing are statistically at a *par* thus produced moderate crop injury score in both locations and in both years.

The effect of time of phosphorus application on crop injury score was significant at Samaru in both years and mean only. Application of phosphorus at sowing significantly resulted in higher crop injury than phosphorus application at 2 weeks before sowing groundnut. There was no significant effect of factor on crop injury score.

4.8.3 Crop Injury Score (9 WAS)

Table 24 shows the crop injury score at 9 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet season. The effect of groundnut variety on crop injury score was significant at all locations in both years and the mean. SAMNUT-23 consistently had the most injurious crop stand when compared to other varieties in both locations, years and the average. SAMNUT-22 produced moderate injured crop across locations, years and the average. Likewise, SAMNUT-24 had the least injured crop stand at both locations and years but this was similar to SAMNUT-22 in 2018 at Samaru.

Table 24: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Injury Score at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Injury Score at 9 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	2.93b	2.93b	2.93b	2.93b	3.36b	3.15b
SAMNUT- 23	4.10a	3.23a	3.66a	3.33a	3.90a	3.61a
SAMNUT -24	2.70b	2.33c	2.51c	2.16c	2.73c	2.45c
S.E±	0.145	0.090	0.087	0.126	0.084	0.082
Weed control method (W)						
Weedy check	5.61a	4.94a	5.27a	4.389a	6.27a	5.33a
Black polythene mulch	1.38c	1.00d	1.19d	1.722b	1.22c	1.47c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	3.33b	3.27b	3.30b	3.333a	3.77b	3.55b
Hoe-weeding at 3 and 6 WAS	2.05c	1.72c	1.88c	1.333b	1.83c	1.58c
Intra-row spacing (10 cm)	3,83b	3.22b	3.52b	3.278a	3.55b	3.41b
S.E.±	0.273	0.188	0.167	0.498	0.260	0.238
Time of phosphorus application (P)						
2 weeks before sowing	2.91b	2.71	2.81b	2.84	3.33	3.08
At sowing	3.57a	2.95	3.26a	2.77	3.33	3.05
S.E±	0.172	0.119	0.105	0.315	0.164	0.150
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The effect of weed control methods on crop injury score was significant at both locations and years. Weedy check consistently produced the most injured crop but this was similar to pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing at Minjibir in 2018. Black polythene mulch significantly gave the least injured plants across the locations, years and combined though statistically at par with hoe weeding at 3 and 6 WAS in most instance except for hoe weeding at 3 and 6 WAS at Samaru 2019 and combined. While pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing are at a *par* and produced moderate injured score in both locations and years.

The effect of time of phosphorus application on crop injury score was significant at Samaru in 2018 and the average. Application of phosphorus at sowing resulted in significantly higher injured crops than phosphorus application at 2 weeks before sowing groundnut. There was no significant effect of factor on crop injury score.

4.8.4 Crop Injury Score (12 WAS)

Table 25 shows the crop injury score at 12 WAS as influenced by groundnut variety, weed control methods and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet season. The effect of groundnut variety on crop injury score was significant at all locations in both years and the mean. SAMNUT-23 consistently had the most injured crop stand but similar to SAMNUT-24 at Samaru in 2018 and SAMNUT-22 at Minjibir in 2018 and the mean. SAMNUT-24 had the least injured crop stand at both locations and years but this was similar to SAMNUT-22 in both years at Samaru and 2019 at Minjibir.

The effect of weed control methods on crop injury score was significant at both locations and in both years. Weedy check consistently produced the most injured crop but this was similar

Table 25: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Injury Score at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Injury Score at 12 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	3.40b	2.33b	2.86b	3.60a	3.16b	3.38a
SAMNUT- 23	3.96a	2.86a	3.41a	3.40ab	3.60a	3.50a
SAMNUT -24	3.56ab	2.00b	2.78b	2.90b	2.90b	2.90b
S.E±	0.162	0.123	0.119	0.219	0.108	0.125
Weed control method (W)						
Weedy check	5.00a	3.55a	4.27a	4.333a	5.22a	4.77a
Black polythene mulch	2.16b	1.00c	1.58c	2.111b	1.00d	1.55c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	4.16a	3.00a	3.58ab	3.556ab	4.11b	3.83b
Hoe-weeding at 3 and 6 WAS	2.38b	2.16b	2.27c	2.111b	1.61c	1.86c
Intra-row spacing (10 cm)	4.50a	2.27b	3.38b	4.389a	4.16b	2.55c
S.E.±	0.430	0.236	0.275	0.498	0.181	0.238
Time of phosphorus application (P)						
2 weeks before sowing	3.26	2.33	2.80	3.55	2.95b	3.25
At sowing	4.02	2.46	3.24	3.04	3.48a	3.26
S.E±	0.272	0.149	0.173	0.315	0.114	0.151
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

to pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Samaru in both years, the mean, in 2018 at Minjibir and 10 cm intra-row spacing at both locations in 2018. Black polythene mulch significantly gave the least injured plants at both locations, in both years and over time, though at a *par* with hoe weeding at 3 and 6 WAS in most instances.

The effect of time of phosphorus application on crop injury score was at Minjibir in 2019. Application of phosphorus at sowing significantly resulted in higher injured crop stand than phosphorus application at 2 weeks before sowing groundnut. There was no significant effect of factor on crop injury score.

4.9 Plant Height (cm)

4.9.1 Plant Height (3 WAS)

The influence of groundnut variety, weed control method and time of phosphorus application on plant height at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet season is presented in Table 26. At both locations, years and the mean, plots grown to SAMNUT-24 produced significantly and consistently taller plants though but this was similar to those grown to SAMNUT-22 at Samaru in 2019. SAMNUT-23 produced the least significant plant height in both locations and years, except at Samaru in 2019.

Weed control method significantly influenced plant height at 3 WAS in both locations, years and over time. Generally, the use of black polythene mulch produced taller groundnut plants; however, plant height in the weedy check in 2018 at both locations, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Samaru in 2019, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing in both years and over time at Samaru and hoe weeding at 3 and 6 WAS in 2018 at Minjibir were comparable. Weedy check produced the least plant height in both locations in 2019 and over time.

Table 26: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Plant Height at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Plant Height at 3 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	15.2b	13.2a	14.1b	14.6b	15.6b	15.1b
SAMNUT- 23	12.3c	11.0b	11.6c	12.1c	11.5c	11.8c
SAMNUT -24	16.2a	13.8a	15.0a	15.9a	16.9a	16.3a
S.E±	0.26	0.42	0.20	0.32	0.34	0.23
Weed control method (W)						
Weedy check	14.5ab	9.8b	12.1b	14.7ab	14.0b	14.3b
Black polythene mulch	15.6a	14.7a	15.1a	15.5a	17.1a	16.3a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	13.5b	13.3a	13.4b	12.8c	13.5b	13.1b
Hoe-weeding at 3 and 6 WAS	14.7ab	12.6a	13.6ab	14.6ab	13.5b	14.4b
Intra-row spacing (10 cm)	14.4ab	12.9a	13.6ab	13.4bc	14.6b	14.0b
S.E.±	0.49	0.76	0.53	0.48	0.73	0.46
Time of phosphorus application (P)						
2 weeks before sowing	14.8	12.5	13.6	14.4	14.8	14.6
At sowing	14.3	12.8	13.5	14.0	14.5	14.2
S.E±	0.31	0.48	0.34	0.30	0.46	0.29
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Time of phosphorus application had no significant influence on plant height at 3 WAS in both locations, years and over time. Similarly, the effects of factor interactions on plant height were not significant.

4.9.2 Plant Height (6 WAS)

The influence of groundnut variety, weed control method and time of phosphorus application on plant height at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet season is presented in Table 27. At both locations, years and the mean, plots grown to SAMNUT-24 produced significantly and consistently taller plants, which was followed by SAMNUT- 22 and SAMNUT- 23 had the shortest plants except at Samaru in 2019 where SAMNUT- 22 and SAMNUT-24 had statistically similar height.

Weed control method significantly influenced plant height at 6 WAS in both locations, years and over time. Generally, the use of black polythene mulch produced taller groundnut plants; however, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Minjibir in 2018, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing at Samaru in 2019 and Minjibir in 2018 were comparable. Weedy check produced the least plant height in both locations, in both years and mean, at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing at Samaru in 2018 only, 2019 at Minjibir and over time.

Time of phosphorus application had no significant influence on plant height at 6 WAS in both locations, years and over time. Similarly, the effects of factor interactions on plant height were not significant.

Table 27: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Plant Height at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Plant Height at 6 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	24.9b	33.2a	29.0b	24.2b	24.1b	24.1b
SAMNUT- 23	21.4c	29.6b	25.5c	20.2c	18.5c	19.3c
SAMNUT -24	31.9a	36.3a	34.1a	31.8a	29.3a	30.6a
S.E±	0.48	1.13	0.62	0.66	0.78	0.55
Weed control method (W)						
Weedy check	25.7b	17.8b	21.7c	22.4b	20.6b	21.5b
Black polythene mulch	28.9a	41.6a	35.2a	26.7a	33.8a	30.3a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	25.1b	35.8a	30.4b	26.5a	21.5b	23.9b
Hoe-weeding at 3 and 6 WAS	25.7b	35.6a	30.6b	26.9a	21.5b	24.2b
Intra-row spacing (10 cm)	25.1b	34.5a	29.8b	24.7ab	22.3b	23.5b
S.E.±	0.75	2.90	1.48	1.03	1.55	1.13
Time of phosphorus application (P)						
2 weeks before sowing	26.1	33.4	29.7	25.6	23.2	24.4
At sowing	26.1	32.7	29.4	25.2	24.7	24.9
S.E±	0.47	1.83	0.94	0.65	0.98	0.71
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan’s Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.9.3 Plant Height (9 WAS)

The influence of groundnut variety, weed control method and time of phosphorus application on plant height at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet season is presented in Table 28. At both locations, years and the mean, plots grown to SAMNUT-24 produced significantly and consistently taller plants. SAMNUT-22 and SAMNUT-23 significantly produced medium plants height in both years at Minjibir and at Samaru in 2018. Also SAMNUT-23 significantly produced least plant height in 2019 at Samaru and the mean.

Weed control method significantly influenced plant height at 9 WAS in both locations, years and the mean. Black polythene mulch produced taller groundnut plants; however, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and hoe weeding at 3 and 6 WAS in 2018 at Minjibir and 10 cm intra-row spacing in 2018 at both locations were comparable. Weedy check produced the least plant height in both locations, years and the mean in most cases though statistically at a *par* with other weed control methods in both years, locations and the mean.

Time of phosphorus application had no significant influence on plant height at 9 WAS in both locations, years and over time. Similarly, the effects of factor interactions on plant height were not significant.

4.9.4 Plant Height (12 WAS)

The influence of groundnut variety, weed control method and time of phosphorus application on plant height at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet season is presented in Table 29. At both locations, years and the mean, plots grown to SAMNUT-24 produced significantly and consistently taller plants. SAMNUT-22 significantly

Table 28: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Plant Height at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Plant Height at 9 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	38.4b	48.5b	43.4b	30.7b	28.5b	29.5b
SAMNUT- 23	35.9b	40.3c	38.0c	27.6b	26.7b	27.1b
SAMNUT -24	46.2a	55.3a	50.7a	39.4a	32.9a	36.1a
S.E±	1.53	1.26	1.13	1.45	1.47	0.91
Weed control method (W)						
Weedy check	37.4b	31.1c	34.2c	29.6b	25.5b	27.5b
Black polythene mulch	46.9a	59.4a	53.1a	35.1a	40.2a	37.6a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	38.3b	47.0b	42.6b	33.8ab	23.1b	28.4b
Hoe-weeding at 3 and 6 WAS	37.5b	51.0b	42.6b	32.4ab	27.8b	30.1b
Intra-row spacing (10 cm)	40.6ab	51.5b	46.1b	31.9ab	30.2b	31.0b
S.E.±	2.28	2.18	1.82	1.50	2.30	1.61
Time of phosphorus application (P)						
2 weeks before sowing	40.3	47.6	43.9	31.8	29.9	30.8
At sowing	40.0	48.4	44.2	33.2	28.9	31.0
S.E±	1.44	1.38	1.15	0.95	1.45	1.02
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 29: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Plant Height at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Plant Height at 12 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	45.3b	58.2b	51.8b	33.1b	30.4b	31.7b
SAMNUT- 23	43.8b	51.0c	47.4c	34.1b	25.8c	30.0b
SAMNUT -24	54.5a	64.6a	59.6a	50.0a	40.9a	45.5a
S.E±	1.13	1.47	0.90	1.23	1.29	1.03
Weed control method (W)						
Weedy check	47.8	40.1c	43.9c	36.4b	25.3c	30.8b
Black polythene mulch	51.7	72.2a	61.9a	41.7a	43.8a	42.7a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	46.5	55.8b	51.1b	36.8b	30.5bc	33.6b
Hoe-weeding at 3 and 6 WAS	45.9	63.1b	54.5b	43.9a	34.5b	39.2a
Intra-row spacing (10 cm)	47.6	58.6b	53.1b	36.6b	27.9c	32.2b
S.E.±	1.98	2.47	1.86	1.40	1.67	1.26
Time of phosphorus application (P)						
2 weeks before sowing	47.9	57.7	52.8	39.5	32.0	35.7
At sowing	47.8	58.3	53.0	38.7	32.7	35.7
S.E±	1.25	1.56	1.18	0.88	1.05	0.79
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

produced moderate plant height in both years, locations and over time; though at a *par* with SAMNUT-23 at both locations in 2018. Also SAMNUT-23 had the least plant height in 2019 at both locations and combined at Samaru.

Weed control method significantly influenced plant height at 12 WAS in both locations, years and the mean, except for 2018 at Samaru. Black polythene mulch produced taller plants; however, plant height in the hoe weeding at 3 and 6 WAS in 2018 at Minjibir and the mean were comparable. Weedy check produced the least plant height in both locations, years and over time in most cases though at a *par* with other the weed control methods in both years, locations and the mean.

Time of phosphorus application had no significant influence on plant height at 12 WAS in both locations, years and over time. Similarly, the effects of factor interactions on plant height were not significant.

4.10 Crop Canopy Spread (cm)

4.10.1 Canopy Spread (3 WAS)

The effects of weed control method and time of phosphorus application on canopy spread at 3 WAS in the three groundnut varieties are presented in Table 30. The groundnut varieties exhibited significant differences in canopy spread at Samaru in 2018 and over time, and also at Minjibir in both years. SAMNUT-24 produced significantly wider canopies at Samaru in 2018 and both years at Minjibir, but at a *par* with SAMNUT-22 at both years in Minjibir. While SAMNUT-23 produced the lowest canopy spread of groundnut.

The effect weed control method on canopy spread was significant at Samaru in 2018 and Minjibir in 2019. Black polythene mulch gave significantly recorded wider canopy. Weedy check produced significantly the least canopy, but this was similar to that under the other

Table 30: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Canopy Spread at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Canopy Spread at 3 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	8.90b	11.64	10.27a	11.65a	13.72a	12.69b
SAMNUT- 23	6.32c	10.26	8.29b	7.92b	10.26b	9.09c
SAMNUT -24	10.03a	13.17	11.60a	17.10a	16.39a	16.75a
S.E±	0.297	1.171	0.595	2.108	1.173	1.164
Weed control method (W)						
Weedy check	7.62b	9.72	8.67b	11.37	10.33b	10.85ab
Black polythene mulch	11.66a	13.06	12.36a	12.12	22.15a	17.14a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	6.96b	10.47	8.72b	8.59	12.35b	10.47b
Hoe-weeding at 3 and 6 WAS	8.15b	14.41	11.28ab	11.93	10.47b	11.20ab
Intra-row spacing (10 cm)	7.70b	10.77	9.23b	17.11	11.97b	14.54ab
S.E.±	0.458	1.930	0.969	3.702	1.890	1.982
Time of phosphorus application (P)						
2 weeks before sowing	9.07a	10.82	9.94	13.77	12.71	13.24
At sowing	7.76b	12.56	10.16	10.68	14.20	12.44
S.E±	0.289	1.221	0.613	2.341	1.195	1.254
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

weed control methods. The effect of time of phosphorus application on canopy spread was significant at Samaru in 2018. Application of phosphorus 2 weeks before sowing resulted in significantly wider canopy than phosphorus application at sowing. There were no significant interaction effects on groundnut canopy spread.

4.10.2 Canopy Spread (6 WAS)

The effects of weed control method and time of phosphorus application on canopy spread at 6 WAS in the three groundnut varieties are presented in Table 31. The groundnut varieties exhibited significant differences in canopy spread with SAMNUT-24 consistently produced wider canopy though at a *par* with SAMNUT-22 at Minjibir in 2019, while SAMNUT-23 produced the lowest canopy in 2018 at Samaru and the mean at Minjibir.

The effect of weed control method on canopy spread was significant at both locations and years. Black polythene mulch gave significantly wider canopy at both locations, years and the mean though at a *par* with hoe weeding at 3 and 6 WAS over time at Samaru, 2018 at Minjibir. Weedy check produced the lowest canopy at both locations, years and over time in most cases though statistically at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, 10 cm intra-row spacing and hoe weeding at 3 and 6 WAS in both years, locations and the average.

Time of phosphorus application had no significant influence on canopy spread in both locations, in both years and over time. There were no significant interaction effects on groundnut canopy spread.

Table 31: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Canopy Spread at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Canopy Spread at 6 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	19.20b	24.70b	21.95b	14.81b	24.53a	19.67b
SAMNUT- 23	15.32c	20.90b	18.11b	13.47b	14.96b	14.22c
SAMNUT -24	25.93a	43.46a	34.69a	21.16a	29.98a	25.57a
S.E±	0.914	5.364	2.698	0.894	2.813	1.541
Weed control method (W)						
Weedy check	15.14 c	22.48	18.81b	15.31b	13.16b	14.24b
Black polythene mulch	29.88a	38.55	34.22a	19.29a	47.24a	33.27a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	17.47bc	36.43	26.95ab	13.98b	18.69b	16.34b
Hoe-weeding at 3 and 6 WAS	20.20b	31.20	25.70ab	19.84a	21.36b	20.60b
Intra-row spacing (10 cm)	18.05bc	19.76	18.90b	13.97b	15.32b	14.65b
S.E.±	1.399	6.318	3.094	1.305	4.244	2.447
Time of phosphorus application (P)						
2 weeks before sowing	21.35	28.56	24.96	16.87	21.66	19.26
At sowing	18.94	30.81	24.88	16.09	24.66	20.37
S.E±	0.885	3.995	1.957	0.825	2.684	1.547
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan’s Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.10.3 Canopy Spread (9 WAS)

The effects of weed control method and time of phosphorus application on canopy spread at 9 WAS in the three groundnut varieties are presented in Table 32. The groundnut varieties exhibited significant differences in canopy spread with SAMNUT-24 consistently produced wider canopy at both locations, in both years and the mean. SAMNUT-23 produced the lowest canopy at Samaru in 2019 and over time.

The effect of weed control method on canopy spread was significant at both locations and years. Black polythene mulch produced the highest canopy at both locations, years and the mean, though at a *par* with hoe weeding at 3 and 6 WAS in 2018 at both locations and the mean at Samaru. Weedy check produced the lowest canopy spread at both locations, years and over time in most cases though at a *par* with that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing in both years, locations and the mean.

Time of phosphorus application had no significant influence on canopy spread in both locations, in both years and over time. There were no significant interaction effects on groundnut canopy spread.

4.10.4 Canopy Spread (12 WAS)

The effects of weed control method and time of phosphorus application on canopy spread at 12 WAS in the three groundnut varieties are presented in Table 33. The groundnut varieties exhibited significant differences in canopy spread with SAMNUT-24 consistently produced wider canopy at both locations, in both years and the mean. SAMNUT-23 produced lower canopy at Samaru in 2018 and the mean while SAMNUT-22 produced moderate canopy though at a *par* with SAMNUT-23 at Samaru in 2019, at Minjibir in 2018 and over time.

Table 32: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Canopy Spread at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Canopy Spread at 9 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	51.01b	57.91b	54.46b	52.73b	19.74b	22.27b
SAMNUT- 23	45.70b	40.93c	43.31c	60.76b	15.31b	22.48b
SAMNUT -24	65.70a	83.90a	81.63a	121.66a	40.29a	50.29a
S.E±	3.451	5.879	3.719	7.408	4.501	4.563
Weed control method (W)						
Weedy check	45.04c	44.01c	44.52b	54.21c	11.03b	21.46bc
Black polythene mulch	64.41a	111.73a	88.07a	96.42ab	57.08a	56.68a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	48.02bc	46.44c	47.23b	72.29bc	15.92b	23.11bc
Hoe-weeding at 3 and 6 WAS	59.87ab	72.13b	77.38a	117.62a	28.31b	38.86b
Intra-row spacing (10 cm)	53.34abc	30.28c	41.81b	51.38c	13.22b	18.24c
S.E.±	4.468	8.147	5.568	11.911	5.676	5.847
Time of phosphorus application (P)						
2 weeks before sowing	52.99	56.76	59.43	77.93	26.40	32.44
At sowing	55.27	65.07	60.17	78.84	23.82	30.92
S.E±	2.826	5.152	3.521	7.533	3.590	3.698
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 33: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Canopy Spread at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Canopy Spread at 12 WAS (cm)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	83.48b	71.13b	77.31b	72.48b	54.24b	63.35b
SAMNUT- 23	69.05c	55.96b	62.51c	78.74b	38.93b	58.83b
SAMNUT -24	101.95a	152.34a	127.15a	143.69a	78.39a	108.95a
S.E±	3.798	6.351	3.415	9.151	7.417	5.887
Weed control method (W)						
Weedy check	71.39c	35.64d	53.52d	79.60bc	18.09c	45.51b
Black polythene mulch	117.40a	169.60a	143.50a	122.15ab	118.22a	120.19a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	76.12c	86.18bc	81.15c	90.94abc	47.77b	69.36b
Hoe-weeding at 3 and 6 WAS	95.48b	122.93ab	109.21b	128.80a	62.16b	95.34a
Intra-row spacing (10 cm)	63.74c	51.40cd	57.57cd	70.01c	39.69bc	54.85b
S.E.±	4.307	15.713	8.472	14.980	8.367	8.443
Time of phosphorus application (P)						
2 weeks before sowing	81.56	93.21	87.38	94.32	56.77	75.49
At sowing	88.10	93.09	90.59	102.28	57.60	78.61
S.E±	2.724	9.938	53.58	9.474	5.292	5.340
Interactions						
V x W	NS	NS	*	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

The effect of weed control method on canopy spread was significant at both locations and years and the mean. Black polythene mulch gave significantly wider canopy at both locations, years and the mean though at a *par* with that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Minjibir in 2018, hoe weeding at 3 and 6 WAS at Samaru in 2019, Minjibir in 2018 and over time. Weedy check had the lowest canopy at both locations, years and over time.

Time of phosphorus application had significant interaction effects on canopy spread at 12 WAS in 2018 and 2019 wet season combined at Samaru.

The interaction effect of variety and weed control method on canopy spread was significant at 12 WAS in 2018 and 2019 wet season over time at Samaru (Table 34). Application of the weed control methods significantly increased canopy only on plots sown to SAMNUT-24, where application of black polythene mulch and hoe weeding at 3 and 6 WAS produced significantly the wider canopy spread than other methods. Across groundnut varieties, significant increase in canopy spread was recorded only with use of black polythene mulch and hoe weeding at 3 and 6 WAS where SAMNUT 24 had wider canopy than the other varieties.

Table 34: Interaction Effect of Groundnut Variety and Weed Control Method on Canopy Spread at 12 WAS in 2018 and 2019 wet season over time at Samaru

	Varieties		
Weed control methods	SAMNUT -22	SAMNUT -23	SAMNUT-24
Weedy check	241bc	195c	285bc
Black polythene mulch	485b	426bc	1026a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	489b	395bc	435bc
Hoe-weeding at 3 and 6 WAS	336bc	313bc	824a
Intra-row spacing (10 cm)	299bc	187c	289bc
SE±		145.0	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance

4.11 Days to 50 Percent Flowering

Days to 50 percent flowering as influenced groundnut variety weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet season is presented in Table 35. In both years and locations, SAMNUT-24 consistently flowered significantly earlier than the other two varieties. SAMNUT-23 in 2019 and over time at both locations was intermediate in earliness to flowering, while SAMNUT-22 generally flowered late although it was at *par* with SAMNUT-23 in 2018 at both locations.

Weed control methods significantly influenced days to 50 percent flowering at both locations, in both years and over time. Generally, earlier flowering was recorded in black polythene mulch, followed by hoe weeding at 3 and 6 WAS in 2019 and over time at Samaru, and both years and over time at Minjibir. The other weed control methods delayed flowering similarly.

Time of phosphorus application had no significant effect on days to 50 percent flowering at both locations, in both years and over time. Factor interacting on days to 50 percent flowering were not significant.

4.12 Nodules Count

4.12.1 Nodules Count (30 Days)

The response of groundnut nodule production at 30 days after sowing (DAS) groundnut varieties on weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons is presented in Table 36. SAMNUT-24 produced significantly and consistently higher nodule at both locations, in both years and over time, but nodule counts in the latter were at a *par* with SAMNUT-22 at Minjibir in both years and over time. SAMNUT-23 produce lower nodule count at both locations, in both years and over time, but was at a *par* SAMNUT- 22 in both years and over time at Samaru.

Table 35: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Day to 50 Percent Flowering at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Day to 50 Percent Flowering					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	28.56a	36.40a	32.48a	29.13a	36.10a	32.61a
SAMNUT- 23	28.73a	29.03b	28.88b	29.50a	29.96b	29.73b
SAMNUT -24	25.43b	23.83c	24.63c	27.16b	23.733c	25.45c
S.E±	0.367	0.372	0.304	0.396	0.386	0.267
Weed control method (W)						
Weedy check	29.00a	32.16a	30.58a	31.333a	32.94a	32.13a
Black polythene mulch	23.00b	22.88c	22.94c	24.722c	23.33c	24.02c
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	28.83a	32.33a	30.58a	29.167ab	32.27ab	30.72ab
Hoe-weeding at 3 and 6 WAS	27.77a	28.94b	28.36b	28.500b	29.94b	29.22b
Intra-row spacing (10 cm)	29.28a	32.44a	30.86a	29.278ab	31.16ab	30.22b
S.E.±	0.888	0.792	0.635	0.846	0.799	0.578
Time of phosphorus application (P)						
2 weeks before sowing	27.26	29.62	28.44	28.48	29.88	29.18
At sowing	27.88	29.88	28.88	28.71	29.97	29.34
S.E±	0.561	0.500	0.402	0.535	0.505	0.365
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 36: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Nodules Count at 30 DAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Nodules Count at 30 DAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	119.8ab	135.5b	127.6b	145.4a	142.0a	143.7a
SAMNUT- 23	117.0b	128.7c	122.8b	87.0b	102.0b	94.4b
SAMNUT -24	142.9a	152.5a	147.7a	146.3a	125.4a	135.8a
S.E+	8.50	2.28	4.26	11.91	6.70	7.80
Weed control method (W)						
Weedy check	133.3ab	106.4d	119.9b	88.1b	109.5b	98.8b
Black polythene mulch	142.6a	164.5a	153.5a	113.1ab	147.8a	130.5ab
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	115.2ab	137.9b	126.5b	142.8a	110.3b	126.5ab
Hoe-weeding at 3 and 6 WAS	138.5ab	168.0a	153.3a	135.7ab	142.4ab	139.0a
Intra-row spacing (10 cm)	103.2b	117.5c	110.3b	151.3a	105.5b	128.4ab
S.E.+	5.19	3.15	6.42	15.45	11.49	10.96
Time of phosphorus application (P)						
2 weeks before sowing	122.9	134.4b	128.7	135.2	127.5	131.3
At sowing	130.2	143.4a	136.8	117.2	118.8	118.0
S.E+	7.379	1.99	4.06	9.77	7.27	6.93
Interactions						
V x W	NS	*	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

The influence of weed control methods on nodules counts at 30 DAS was significant at both locations, in both years and over time. Black polythene mulch and hoe weeding at 3 and 6 WAS gave significantly and consistently higher nodule counts, but these were at a *par* with weedy check and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 at Samaru, 10 cm intra-row spacing and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 and over time at Minjibir. However, weedy check produced significantly lower nodule counts in most cases across locations, years and over time, but these were similar to those records in pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing.

The effect of time of phosphorus application on nodule count at 30 DAS was significant at Samaru in 2019. Application of phosphorus at sowing gave significantly higher nodule count than phosphorus application at 2 weeks before sowing. Similarly, the effects of factor interactions on nodule counts were significant only at Samaru in 2019.

The interaction effect of variety and weed control method on nodule count was significant at 30 DAS the in 2019 wet season at Samaru (Table 37). Application of weed control method significantly increased nodule count only on plots sown to SAMNUT-24, where black polythene mulch and hoe weeding at 3 and 6 WAS gave significantly higher nodule counts, than other methods except in SAMNUT- 22 in which hoe weeding at 3 and 6 WAS also produced similar nodule counts.

Table 37: Interaction Effect of Groundnut Variety and Weed Control Method on Nodule Count at 30 DAS at Samaru during the 2019 wet season.

	Variety		
Weed control methods	SAMNUT- 22	SAMNUT- 23	SAMNUT- 24
Weedy check	96.9e	101.9e	120.7cd
Black Polythene mulch	149.9b	155.3b	188.5a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	131.7c	127.8c	154.3b
Hoe-weeding at 3 and 6 WAS	178.1a	152.1b	173.9a
Intra-row spacing (10 cm)	121.1cd	106.4de	125.3c
SE±		12.30	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

Across groundnut varieties, significant increase in nodule count was recorded only black polythene mulch and hoe weeding at 3 and 6 WAS, where SAMNUT-24 had more nodule count than the other varieties.

4.12.2 Nodule count (60 DAS)

The response nodule production at 60 days after sowing (DAS) groundnut varieties on weed control methods and time of phosphorus application at both locations, years and over time is presented in Table 38. SAMNUT-24 at Samaru in both years and over time produced significantly higher nodule counts than other varieties though at a *par* with SAMNUT-22 at Samaru in 2018. While SAMNUT-23 had fewer nodule counts than SAMNUT -22 only in 2018 and the mean. At Minjibir in 2018, 2019 and the mean, SAMNUT-22 significantly produced more nodule counts than to SAMNUT- 23, but in 2018 it had more nodule counts when compared to SAMNUT 24.

Weed control method on nodule counts at 60 DAS was significant at both locations, in both years and over time. Hoe weeding at 3 and 6 WAS gave significantly and consistently higher nodule counts, but statistically at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 at Samaru and the mean of black polythene mulch at Samaru. Weedy check significantly recorded lower nodule counts most cases at both locations, years and over time. 10 cm intra-row spacing produced moderate nodule counts in most cases at both locations, years and the mean, but these were similar to those records in black polythene mulch and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}.

Time of phosphorus application on nodule counts was not significant at both locations, in both years and the mean. There were no significant interaction effects on nodule counts at 60 DAS.

Table 38: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Nodules count at 60 DAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Nodules count at 60 DAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	65.7a	64.7b	65.2b	74.5a	59.7a	67.1a
SAMNUT- 23	47.2b	57.7b	52.4c	65.6b	47.9b	56.7b
SAMNUT -24	67.1a	87.3a	77.2a	62.4b	67.3a	64.8a
S.E±	3.91	3.37	2.58	2.98	3.37	2.09
Weed control method (W)						
Weedy check	44.7c	31.4c	38.1c	37.1d	20.1c	28.6d
Black polythene mulch	75.8a	88.7b	82.2a	67.1bc	77.0b	72.0b
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	59.7abc	52.5c	56.1b	62.9c	40.8c	51.8c
Hoe-weeding at 3 and 6 WAS	61.6ab	119.7a	90.6a	96.6a	108.0a	102.3a
Intra-row spacing (10 cm)	58.1bc	57.3c	57.7b	73.7b	45.7c	59.7bc
S.E.±	11.66	8.45	4.74	2.58	8.44	4.61
Time of phosphorus application (P)						
2 weeks before sowing	60.3	72.1	66.2	69.3	60.5	64.8
At sowing	59.6	67.7	63.7	65.7	56.2	60.9
S.E±	3.28	5.34	3.00	1.63	5.34	2.92
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.13 Crop Growth Rate (g m^{-2} wk^{-1})

4.13.1 Crop growth rate (6 WAS)

The effect of weed control method and time of phosphorus application on crop growth rate (CGR) in groundnut varieties at 6 WAS is presented in Table 39. The groundnut varieties exhibited significant differences in crop growth rate. SAMNUT- 24 showed higher CGR than other varieties at both locations, in both years and over time although similar to SAMNUT-22. SAMNUT-23 showed the lowest CGR at both locations, in both years and over time. However, CGR in SAMNUT- 23 was comparable to that in SAMNUT-22 over time at Minjibir.

The response of CRG to weed control method was significant at both locations, in both years and over time. Black polythene mulch produced significantly and consistently higher CRG at both locations, in both years and over time than other weed control methods. However, these were similar to hoe weeding at 3 and 6 WAS in both years and over time at Samaru and in 2018 at Minjibir. Weedy check gave significantly lower CGR at both locations, in both years and over time these were generally at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing.

The effect of time of phosphorus application on CGR was significant at both locations, years and over time, except in 2019 at Minjibir where CGR was similar across the time of P application. Application of phosphorus at 2 weeks before sowing groundnut resulted in significantly higher than CGR phosphorus application at sowing. Generally, factor interactions did not significantly affect CGR.

Table 39: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Growth Rate at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Growth Rate at 6 WAS (g m^{-2} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	30.84a	40.71a	35.78a	26.28a	38.63ab	32.45b
SAMNUT- 23	25.68b	29.73b	27.70b	18.37b	34.62b	26.50c
SAMNUT -24	34.11a	46.94a	40.53a	31.37a	43.63a	37.50a
S.E±	1.345	2.761	2.024	2.027	2.557	1.567
Weed control method (W)						
Weedy check	20.71d	19.99c	20.35d	11.60d	31.481b	21.54c
Black polythene mulch	37.83a	53.84a	45.84a	36.34a	54.65a	45.49a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	26.51cd	30.87bc	28.69dc	19.30dc	37.37b	28.34bc
Hoe-weeding at 3 and 6 WAS	35.50ab	49.68a	42.59ab	33.09ab	40.50b	36.83b
Intra-row spacing (10 cm)	30.51bc	41.95ab	35.88bc	26.38bc	38.74b	28.56bc
S.E.±	2.127	4.173	3.124	3.062	3.826	2.754
Time of phosphorus application (P)						
2 weeks before sowing	36.96a	52.53a	44.75a	35.25a	39.11	37.18a
At sowing	23.46b	25.72b	24.59b	15.44b	38.81	27.12b
S.E±	1.345	2.639	1.976	1.936	2.420	1.741
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.13.2 Crop growth rate (9 WAS)

The effect of weed control method and time of phosphorus application on crop growth rate (CGR) in groundnut varieties at 9 WAS is presented in Table 40. The groundnut varieties exhibited significant differences in crop growth rate in both locations, years and except for the mean in 2018 at Minjibir. SAMNUT-24 showed higher CGR than other varieties at Samaru in 2018 and the mean. SAMNUT-23 had the lowest CGR at Minjibir in 2019 and the mean when compared to SAMNUT 22 only at Samaru in 2019.

The response of CGR to weed control method was significant at both locations, in both years and over time. Black polythene mulch produced significantly and consistently higher CGR at both locations, in both years and over time than other weed control methods. However, these were similar to hoe weeding at 3 and 6 WAS at both years at Samaru, weedy check in 2018 at Minjibir, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 at Minjibir and hoe weeding at 3 and 6 WAS at Minjibir in 2018. 10 cm intra-row spacing had the least value of crop growth rate at both locations, years and the mean. But at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and weedy check.

Time of phosphorus application had no significant effect on days to CGR at both locations, in both years and over time. Factor interacting on CGR were not significant.

Table 40: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Crop Growth Rate at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Growth Rate at 9 WAS (g m^{-2} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	35.76b	65.15a	50.45b	40.52	49.34ab	44.92ab
SAMNUT- 23	27.69b	52.61b	40.15c	45.55	38.70b	42.12b
SAMNUT -24	47.39a	69.61a	58.50a	46.32	67.19a	56.75a
S.E+	3.849	2.776	2.312	2.332	8.166	4.143
Weed control method (W)						
Weedy check	25.91c	43.77c	34.84c	39.96ab	22.33b	31.15b
Black polythene mulch	60.79a	83.66a	72.23a	52.57a	123.62a	88.10a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	30.41bc	53.83bc	42.12c	40.81ab	40.29b	40.53b
Hoe-weeding at 3 and 6 WAS	47.24ab	69.23ab	58.24b	51.87a	38.43b	45.15b
Intra-row spacing (10 cm)	20.38c	61.79bc	41.08c	35.44b	34.09b	34.77b
S.E.+	5.938	6.404	3.852	4.028	15.156	8.425
Time of phosphorus application (P)						
2 weeks before sowing	38.02	63.01	50.52	44.63	50.37	47.49
At sowing	35.88	61.90	48.89	43.63	53.12	48.37
S.E+	3.756	4.050	2.436	2.547	9.586	5.329
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.13.3 Crop growth rate (12 WAS)

The effect of weed control method and time of phosphorus application on crop growth rate (CGR) in groundnut varieties at 12 WAS is presented in Table 41. The groundnut varieties exhibited significant difference in crop growth rate in 2018 at Minjibir. SAMNUT-22 and SAMNUT-24 significantly produced higher CGR in 2018 at Minjibir while SAMNUT-23 recorded lower CGR.

The response of CGR to weed control method was significant at both locations and years and the average. Black polythene mulch produced significantly and consistently higher crop growth rate at both locations, in both years and the mean than other weed control methods. However, these were similar to pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing all in 2018 at Minjibir only and both years at Samaru and the mean. Weedy check had lower CGR at both locations, years and over time.

Time of phosphorus application had no significant effect on days to CGR at both locations, in both years and over time. Factor interacting on CGR were not significant.

4.14 Relative Growth Rate (g g^{-1} wk^{-1})

4.14.1 Relative growth rate (6 WAS)

Relative growth rate (RGR) of groundnut variety at 6 WAS as influenced by weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons are presented in Table 42. SAMNUT-23 in both locations in 2018 significantly recorded higher RGR though statistically the same with SAMNUT-22 in 2018 at Samaru and SAMNUT-24 at both years and the mean at Minjibir. SAMNUT-22 had lower RGR at both years at Minjibir but at a *par* with SAMNUT-23 in 2019 and over time at Minjibir and SAMNUT-24 in 2018 at Samaru.

Table 41: Effect of Groundnut Variety, Weed Management and Time of Phosphorus Application on Crop Growth Rate at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Crop Growth Rate at 12 WAS (g m^{-2} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	50.50	48.33	49.41	36.20a	46.90	41.55
SAMNUT- 23	59.48	47.84	53.66	23.90b	52.16	38.03
SAMNUT -24	58.73	48.30	53.52	39.20a	59.63	48.41
S.E±	3.754	3.587	3.364	3.587	8.582	4.777
Weed control method (W)						
Weedy check	42.68b	33.87b	38.28b	33.87b	37.84b	34.56b
Black polythene mulch	59.17ab	47.32ab	53.25ab	47.32ab	92.15a	61.03a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	54.16ab	46.79ab	50.48ab	46.79ab	51.33b	41.90b
Hoe-weeding at 3 and 6 WAS	64.25a	59.17a	61.71a	59.17a	44.18b	40.37b
Intra-row spacing (10 cm)	60.91ab	53.63ab	57.27a	53.63ab	38.00b	35.44b
S.E.±	6.192	6.272	5.707	6.272	10.618	5.465
Time of phosphorus application (P)						
2 weeks before sowing	54.70	46.52	50.61	46.52	40.88b	37.10b
At sowing	57.77	49.80	53.78	49.80	64.90a	48.23a
S.E±	3.916	3.967	3.609	3.967	6.715	3.456
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 42: Effect of Groundnut Variety, Weed Management and Time of Phosphorus Application on Relative Growth Rate at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Relative Growth Rate at 6 WAS (gg^{-1} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.297ab	0.357	0.327	0.303b	0.310b	0.307b
SAMNUT- 23	0.332a	0.330	0.331	0.340a	0.298b	0.319b
SAMNUT -24	0.285b	0.338	0.311	0.309ab	0.393a	0.351a
S.E±	0.0151	0.0116	0.0087	0.0121	0.0135	0.0101
Weed control method (W)						
Weedy check	0.303ab	0.292b	0.297b	0.285b	0.294bc	0.290c
Black polythene mulch	0.289b	0.363a	0.326ab	0.324ab	0.384a	0.354a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.332a	0.334ab	0.333a	0.350a	0.271c	0.310bc
Hoe-weeding at 3 and 6 WAS	0.309ab	0.339a	0.324ab	0.312ab	0380a	0.346ab
Intra-row spacing (10 cm)	0.288b	0.380a	0.334a	0.316ab	0.340ab	0.328ab
S.E.±	0.0132	0.0147	0.0103	0.0195	0.0181	0.0113
Time of phosphorus application (P)						
2 weeks before sowing	0.030	0.394a	0.349a	0.3110	0.352a	0.331
At sowing	0.305	0.289b	0.297b	0.324	0.315b	0.320
S.E±	0.0083	0.0093	0.0065	0.0123	0.0115	0.0071
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The effect of weed control method significantly influenced RGR at both locations, years and average. Hoe weeding at 3 and 6 WAS produced significantly and consistently higher RGR at both locations, years and the mean, although comparable to black polythene mulch, 10 cm intra-row spacing, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 both locations and in 2019 at Minjibir. Weedy check had lower RGR in both locations, years and the mean, though at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2019 and over time at Minjibir.

Time of phosphorus application had significant effect on RGR in 2019 at both locations and over time at Samaru only. Application of phosphorus at 2 weeks before sowing groundnut significantly produced higher RGR than phosphorus application at sowing. Factor interacting on RGR were not significant.

4.14.2 Relative growth rate (9 WAS)

Relative growth rate (RGR) of groundnut variety at 9 WAS as influenced by weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons is presented in Table 43. Groundnut varieties did not have any significant influence on RGR in both locations, years and over time.

The effect of weed control methods significantly influenced RGR in both locations, years and the mean. Hoe weeding at 3 and 6 WAS produced significantly and consistently higher RGR at both locations, years and the mean, although comparable to black polythene mulch, pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, weedy check in 2018 at both locations and over time at Samaru. 10 cm intra-row spacing significantly had lower RGR in both locations, in both years and over time in most cases, though at a *par* with weedy check at Minjibir in 2019 and over time.

Table 43: Response of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Relative Growth Rate at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Relative Growth Rate at 9 WAS (gg^{-1} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.343	0.297	0.320	0.241	0.295	0.268
SAMNUT- 23	0.350	0.312	0.331	0.260	0.310	0.285
SAMNUT -24	0.339	0.293	0.316	0.239	0.307	0.273
S.E±	0.0128	0.0091	0.0093	0.0140	0.0117	0.0111
Weed control method (W)						
Weedy check	0.340ab	0.302	0.321ab	0.216ab	0.273b	0.244b
Black polythene mulch	0.365a	0.306	0.336ab	0.263ab	0.321ab	0.292ab
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.335ab	0.313	0.324ab	0.255ab	0.310ab	0.283ab
Hoe-weeding at 3 and 6 WAS	0.389a	0.313	0.351a	0.296a	0.333a	0.314a
Intra-row spacing (10 cm)	0.291b	0.270	0.280b	0.204b	0.284ab	0.244b
S.E.±	0.0226	0.0176	0.0174	0.0251	0.0160	0.0186
Time of phosphorus application (P)						
2 weeks before sowing	0.348	0.283b	0.315	0.254	0.306	0.280
At sowing	0.341	0.319a	0.330	0.239	0.303	0.271
S.E±	0.0143	0.0111	0.0110	0.0159	0.0101	0.0117
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Time of phosphorus application had significant effect on RGR in 2019 at Samaru. Application of phosphorus at sowing groundnut significantly produced in higher RGR than phosphorus application at 2 weeks before sowing. The factors interacting on RGR was generally not significant.

4.14.3 Relative growth rate (12 WAS)

Relative growth rate (RGR) of groundnut variety at 12 WAS as influenced by weed control method and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet seasons are presented in Table 44. SAMNUT-23 significantly produced higher RGR at Samaru in both years and the mean and also at Minjibir in 2019 though at a *par* with SAMNUT-22 in 2018 at Minjibir and SAMNUT-24 at both locations, years and overtime. SAMNUT-22 had the lowest RGR at both years at Samaru and at Minjibir in 2019.

The effect of weed control methods significantly influenced RGR in both locations, years and over time. Black polythene mulch produced significantly and consistently higher RGR at both locations, years and the mean, though at a *par* with hoe weeding at 3 and 6 WAS. Weedy check had the lowest RGR in both locations, years and over time though comparable with that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing.

Time of phosphorus application had significant effect on RGR at Minjibir in 2019 and the average. Application of phosphorus at sowing groundnut significantly produced higher RGR than phosphorus application at 2 weeks before sowing. Factor interacting on RGR were not significant.

Table 44: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Relative Growth Rate at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Relative Growth Rate at 12 WAS (gg^{-1} wk^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.279b	0.256b	0.268b	0.283a	0.265b	0.274
SAMNUT- 23	0.299a	0.275a	0.287a	0.266b	0.292a	0.279
SAMNUT -24	0.286ab	0.266ab	0.276ab	0.274ab	0.271ab	0.273
S.E±	0.0062	0.0055	0.0041	0.0050	0.0081	0.0045
Weed control method (W)						
Weedy check	0.279bc	0.231b	0.255b	0.252b	0.261b	0.257b
Black polythene mulch	0.309a	0.301a	0.305a	0.293a	0.307a	0.300a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.270c	0.252b	0.261b	0.264b	0.261b	0.263b
Hoe-weeding at 3 and 6 WAS	0.299ab	0.289a	0.294a	0.298a	0.296a	0.297a
Intra-row spacing (10 cm)	0.283abc	0.256b	0.270b	0.264b	0.256b	0.260b
S.E.±	0.0086	0.0095	0.0067	0.0079	0.0094	0.0051
Time of phosphorus application (P)						
2 weeks before sowing	0.290	0.262	0.276	0.273	0.264b	0.268b
At sowing	0.286	0.269	0.278	0.276	0.288a	0.282a
S.E±	0.0054	0.0060	0.0042	0.0050	0.0060	0.0032
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.15 Leaf Area Index

4.15.1 Leaf area index (3 WAS)

Table 45 shows the leaf area index (LAI) at 3 WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet seasons. SAMNUT-24 produced significantly and consistently higher LAI at both locations, in both years and over time but this was similar to that of SAMNUT-22 at Samaru in both years and the mean. SAMNUT-23 gave significantly and consistently lower LAI at both locations, in both years and over time but this was similar to that of SAMNUT-22 at Minjibir in both years and over time.

The response of LAI to weed control method was significant in both locations and years, over time except for 2018 at Samaru. Black polythene mulch and 10 cm intra-row spacing produced significantly and consistently higher LAI in both locations, years and over time though statistically similar with weedy check at Minjibir at both years and combined and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2018 at Minjibir gave similar LAI. Generally, hoe weeding at 3 and 6 WAS in both locations, years and the mean produced the lowest LAI.

The effect of time of phosphorus application on LAI was significant at Samaru in 2019. Application of phosphorus at 2 Weeks before sowing groundnut significantly produced higher LAI than phosphorus application at sowing. There was no significant interaction effects on LAI.

4.15.2 Leaf area index (6 WAS)

Table 46 shows the leaf area index (LAI) at 6 WAS as influenced by groundnut variety, weed control methods and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet seasons. SAMNUT-24 produced significantly and consistently higher LAI at both

Table 45: Effect of Groundnut Varieties to Weed Management Strategies and Time of Phosphorus Application on Leaf Area Index at 3 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Leaf Area Index at 3 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.37ab	0.69a	0.53a	0.33b	0.38b	0.35b
SAMNUT- 23	0.29b	0.56b	0.43b	0.33b	0.34b	0.34b
SAMNUT -24	0.44a	0.73a	0.58a	0.57a	0.54a	0.55a
S.E±	0.033	0.034	0.021	0.025	0.020	0.020
Weed control method (W)						
Weedy check	0.38	0.55c	0.46b	0.432ab	0.43ab	0.43ab
Black polythene mulch	0.44	0.82a	0.63a	0.478a	0.49a	0.48a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.30	0.67bc	0.48b	0.370ab	0.37b	0.36b
Hoe-weeding at 3 and 6 WAS	0.33	0.57bc	0.45b	0.338b	0.36b	0.34b
Intra-row spacing (10 cm)	0.38	0.70ab	0.54ab	0.468a	0.46ab	0.46a
S.E.±	0.058	0.041	0.040	0.041	0.029	0.029
Time of phosphorus application (P)						
2 weeks before sowing	0.39	0.71a	0.55	0.402	0.43	0.41
At sowing	0.34	0.61b	0.48	0.431	0.42	0.42
S.E±	0.036	0.026	0.025	0.026	0.018	0.018
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 46: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Leaf Area Index at 6 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Leaf Area Index at 6 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.98b	0.73ab	0.85b	1.16b	0.91b	1.03b
SAMNUT- 23	0.76c	0.62b	0.69c	1.09b	0.82b	0.95b
SAMNUT -24	1.32a	0.85a	1.09a	1.67a	1.19a	1.43a
S.E±	0.063	0.045	0.051	0.067	0.056	0.057
Weed control method (W)						
Weedy check	0.56b	0.33b	0.46b	1.24	0.52b	0.88b
Black polythene mulch	1.15a	0.97a	1.06a	1.23	1.12a	1.21a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	1.05a	0.69a	0.87a	1.28	1.08a	1.18a
Hoe-weeding at 3 and 6 WAS	1.17a	0.89a	1.03a	1.19	1.00a	1.09ab
Intra-row spacing (10 cm)	1.17a	0.76a	0.96.a	1.50	1.15a	1.32a
S.E.±	0.102	0.120	0.099	0.097	0.071	0.076
Time of phosphorus application (P)						
2 weeks before sowing	1.05	0.65	0.85	1.31	0.93	1.12
At sowing	0.99	0.81	0.90	1.31	1.01	1.16
S.E±	0.065	0.075	0.062	0.061	0.045	0.048
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

locations, years and over time, but this was similar to that of SAMNUT-22 at Samaru in 2019. SAMNUT-23 gave lower LAI in both locations, in both years and over time but this was at a *par* with SAMNUT-22 in 2018 at both locations, over time and SAMNUT-22 at Minjibir in 2019.

The response of LAI to weed control method was significant in both locations and years and over time except for 2018 at Minjibir. Black polythene mulch produced higher significantly and consistently LAI at both locations, in both years and over time, though comparable to pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing. Weedy check significantly had the lowest LAI at both locations, year and combined.

The effect of time of phosphorus application on leaf area index was not significant at both locations, in both years and the mean. There was no significant interaction effects on LAI.

4.15.3 Leaf area index (9 WAS)

Table 47 shows the leaf area index (LAI) at 9 WAS as influenced by groundnut variety, weed control methods and time of phosphorus application at Samaru and Minjibir during 2018 and 2019 wet seasons. SAMNUT-24 significantly produced higher LAI at Samaru in 2019, Minjibir in 2018 the mean of both locations, but this was similar to that of SAMNUT-22 in 2018 both locations. SAMNUT-23 had the least LAI at both locations, in both years and over time but at a *par* with SAMNUT-24 at Samaru in 2018, SAMNUT-22 at Minjibir in 2019 and the mean of both locations.

Table 47: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Leaf Area Index at 9 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Leaf Area Index at 9 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.65a	0.59b	0.61b	1.08a	1.01	1.04b
SAMNUT- 23	0.48b	0.62b	0.55b	1.06b	0.89	0.97b
SAMNUT -24	0.51b	1.10a	0.80a	1.42a	1.00	1.21a
S.E±	0.034	0.047	0.026	0.073	0.045	0.052
Weed control method (W)						
Weedy check	0.23b	0.40c	0.31c	0.061c	0.67b	0.63b
Black polythene mulch	0.68a	1.08a	0.88a	1.64a	0.10a	1.37a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.53a	0.82ab	0.67ab	0.95bc	0.99a	0.97ab
Hoe-weeding at 3 and 6 WAS	0.73a	0.88ab	0.80ab	1.49ab	1.01a	1.25a
Intra-row spacing (10 cm)	0.55a	0.65bc	0.60b	1.23ab	1.08a	1.15a
S.E.±	0.079	0.096	0.070	0.187	0.106	0.142
Time of phosphorus application (P)						
2 weeks before sowing	0.52	0.74	0.633	1.25	0.99	1.12
At sowing	0.57	0.79	0.68	1.12	0.95	1.03
S.E±	0.050	0.060	0.044	0.118	0.067	0.090
Interactions						
V x W	*	*	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.* = Significant at 5 %.

The response of LAI to weed control method was significant at both locations and years and the mean. Black polythene mulch and hoe weeding at 3 and 6 WAS produced significantly and consistently higher LAI at both locations, years and over time but this was similar to that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and 10 cm intra-row spacing in most cases. Weedy check had the least LAI at both locations, year and over time.

Time of phosphorus application had no significant effect on LAI at both locations across the years and the average. The effects of factor interactions on LAI were significant only at Samaru in 2018 and 2019.

The interaction between varieties and weed control method on LAI was significant at Samaru in 2018 wet season (Table 48). The effect of weedy check on SAMNUT-23 significantly produced the lowest LAI though at a *par* with the other groundnut varieties. But the use hoe weeding at 3 and 6 WAS on SAMNUT-22 had the highest LAI though comparable to 10 cm intra-row spacing on SAMNUT-22 and the use of black polythene mulch on SAMNUT-22 and SAMNUT-23, however, beyond this combinations a significance decrease LAI was observed.

Table 48: Interaction Effect of Groundnut Variety and Weed Control Method on Leaf Area Index at 9 WAS of Groundnut at Samaru during the 2018 wet season.

	Variety		
Weed control method	SAMNUT- 22	SAMNUT- 23	SAMNUT-24
Weedy check	0.2783d-g	0.1983g	0.2367fg
Black Polythene mulch	0.7617abc	0.7333abc	0.5733b-f
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.4400c-g	0.5700b-g	0.5950b-f
Hoe-weeding at 3 and 6 WAS	0.9633a	0.6650bc	0.575b-f
Intra-row spacing (10 cm)	0.8117ab	0.2633efg	0.6033bcd
SE±		0.197	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

The interaction between weed control method and groundnut varieties on LAI was significant at Samaru in 2019 as indicated in Table 49. Application of weedy check, with all the groundnut varieties had no significant influence on LAI. But when black polythene mulch, pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluzifop-P-butyl at 1.0 kg a.i. ha^{-1}, hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing, with in plots sown to SAMNUT-22 and SAMNUT-23 had no significant effect on LAI, beyond this rates (use of SAMNUT-24) significant improvement of LAI was achieved. It was observed that plot sown to SAMNUT-22 and SAMNUT-23 had no significant influence on LAI when all the weed control method was deployed. However, plot grown to SAMNUT-24, with the application of black polythene mulch and hoe weeding at 3 and 6 WAS significantly recorded the highest LAI than the other rates.

4.15.4 Leaf area index (12 WAS)

Table 50 shows the leaf area index (LAI) at 12WAS as influenced by groundnut variety, weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. SAMNUT-24 produced significantly higher LAI at Samaru in 2019, Minjibir in both years and over time both locations but this was similar to that of SAMNUT-22 in 2018 at Samaru. SAMNUT-23 had the lowest LAI at both locations, in both years and over time, though statistically at a *par* with SAMNUT-22 in most cases.

The response of LAI to weed control method was significant at both locations and years and the mean. Black polythene produced mulch significantly and consistently higher LAI at both locations, years and over time though at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, hoe weeding at 3 + 6 WAS in most cases and 10 cm intra-

Table 49: Interaction Effect of Groundnut Variety and Weed Control Methods on Leaf Area Index at 9 WAS of Groundnut at Samaru during the 2019 wet season.

	Variety		
Weed control method	SAMNUT-22	SAMNUT- 23	SAMNUT- 24
Weedy check	0.4333ef	0.4033f	0.3683f
Black Polythene mulch	0.8600cde	0.7083c-f	1.6917a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.6317def	0.7533c-f	1.0967bc
Hoe-weeding at 3 and 6 WAS	0.5767def	0.6117def	1.4583ab
Intra-row spacing (10 cm)	0.4500ef	0.6433def	0.8850cd
SE±		0.255	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

Table 50: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Leaf Area Index at 12 WAS at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Leaf Area Index at 12 WAS					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	0.64a	0.91b	0.78b	0.83b	0.73b	0.78b
SAMNUT- 23	0.49b	0.86b	0.68c	0.67b	0.54c	0.60c
SAMNUT -24	0.53b	1.24a	0.88a	1.33a	0.89a	1.11a
S.E$\pm$	0.033	0.036	0.027	0.058	0.029	0.040
Weed control method (W)						
Weedy check	0.27b	0.75c	0.51c	0.67b	0.59c	0.63b
Black polythene mulch	0.66a	1.19a	0.92a	1.20a	0.84a	1.02a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	0.52a	1.18ab	0.85ab	1.80b	0.66ab	0.73b
Hoe-weeding at 3 and 6 WAS	0.73a	1.02b	0.87ab	1.22a	0.78ab	1.00a
Intra-row spacing (10 cm)	0.60a	0.87c	0.73b	0.82b	0.73ab	0.77b
S.E.$\pm$	0.075	0.052	0.047	0.040	0.041	0.045
Time of phosphorus application (P)						
2 weeks before sowing	0.90	0.95b	0.74	1.520	0.73	0.81
At sowing	0.99	1.06a	0.81	1.412	0.71	0.85
S.E$\pm$	0.047	0.033	0.030	0.053	0.026	0.028
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

row spacing at Samaru in 2018 and Minjibir in 2019 except for pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Minjibir in 2018, the mean and hoe weeding at 3 and 6 WAS at Samaru in 2019 which did not differ with that of weedy check.

Time of phosphorus application had significant effect on LAI at Samaru in 2019. Application of phosphorus at sowing groundnut significantly produced higher LAI than phosphorus application at 2 weeks before sowing. There was no significant interaction effects on LAI.

4.16 Pod Yield (kg ha^{-1})

The effects of weed control method and time of phosphorus application on pod yield of groundnut varieties at Samaru and Minjibir during the 2018 and 2019 wet seasons are presented in Table 51. SAMNUT-24 produced significantly more pod yield, followed by SAMNUT-23. However, pod yield in latter was at a *par* with that of SAMNUT-22, except in 2019 at both locations, in both years and over time at Minjibir when the latter produced the lowest pod yield.

Weed management method significantly influenced pod yield of groundnut at both locations, in both years and over time. Black polythene and hoe weeding at 3 and 6 WAS consistently produced higher pod yield than other weed control methods, except weedy check at Samaru in 2018 and pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} at Samaru in 2018 which had similar yield. Weedy check generally gave the least pod yield.

Time of phosphorus application had no significant effect on pod yield kg ha^{-1} of groundnut in both locations, in both years and over time. There were no significant interaction effects among the factors on pod yield.

Table 51: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Pod Yield (kg ha^{-1}) at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Pod Yield (kg ha^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	1478.5b	1883.0c	1680.7b	1375.2b	1805.8c	1590.5c
SAMNUT- 23	1450.8b	2134.9b	1792.8b	1399.6b	2073.1b	1736.3b
SAMNUT -24	1830.5a	2508.2a	2169.3a	1484.8a	2415.2a	1950.0a
S.E±	79.67	79.89	56.41	11.33	88.82	46.11
Weed control method (W)						
Weedy check	1415.3ab	1617.9b	1516.6b	1392.9b	1160.6c	1276.7c
Black polythene mulch	1743.8a	2885.1a	2314.5a	1460.4a	3155.6a	2308.0a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	1651.1ab	1857.3b	1754.2b	1375.3b	1577.8b	1476.6b
Hoe-weeding at 3 and 6 WAS	1727.7a	2501.4a	2114.6a	1473.1a	2892.8a	2182.9a
Intra-row spacing (10 cm)	1395.3b	2015.1b	1705.2b	1387.6b	1703.4b	1550.5b
S.E.±	103.34	139.68	84.11	19.14	106.15	54.90
Time of phosphorus application (P)						
2 weeks before sowing	1563.3	2151.8	1857.5	1418.1	2093.2	1755.7
At sowing	1609.9	2198.9	1904.4	1421.6	2102.8	1762.2
S.E±	65.36	88.34	53.19	12.10	67.13	34.72
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.17 Kernel yield (kg ha^{-1})

The effects of weed control methods and time of phosphorus application on kernel yield of groundnut varieties at Samaru and Minjibir during the 2018 and 2019 wet seasons are presented in Table 52. SAMNUT- 22 generally had higher kernel yield than both SAMNUT-23 and SAMNUT- 24 which were at a *par* at Samaru in both years and over time. At Minjibir, no significant difference in kernel yield was recorded at among groundnut varieties in 2018. However, in 2019 and over time, SAMNUT-22 and SAMNUT-24 produced similar kernel yields that there were significantly higher than in SAMNUT-23.

The effect of weed control methods on kernel yield was significant in both years, location and over time. Black polythene mulch had higher kernel yield, however, this was at a *par* with hoe weeding at 3 and 6 WAS and 10 cm intra-row spacing than other weed control methods in both locations, in both years and over time at Samaru. Weedy check had the least kernel yield at both years at Samaru, over time in both location and in 2019 at Minjibir.

Time of phosphorus application significantly affected kernel yield only at Samaru in 2018. Application of phosphorus at sowing produced higher kernel yield than phosphorus application at 2 weeks before sowing. There were no significant factor interaction effect kernel yield.

Table 52: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Kernel Yield (kg ha^{-1}) at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Kernel Yield (kg ha^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	50.05a	73.81a	61.93a	49.87	60.43a	55.15a
SAMNUT- 23	44.97b	61.07b	53.02b	47.52	51.63b	49.58b
SAMNUT -24	44.00b	66.03b	55.01b	47.37	58.27a	52.82a
S.E±	0.472	1.930	0.961	0.940	1.963	1.117
Weed control method (W)						
Weedy check	45.61b	59.56b	52.59b	48.53ab	42.70b	45.61c
Black polythene mulch	46.80ab	71.29a	59.05a	51.16a	63.79a	57.48a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	45.53b	67.56ab	56.54ab	47.06b	59.88a	53.47b
Hoe-weeding at 3 and 6 WAS	47.59a	65.09ab	56.34ab	48.34ab	57.03a	52.69b
Intra-row spacing (10 cm)	46.15ab	71.35a	58.75a	46.18b	60.49a	53.33b
S.E.±	0.568	3.294	1.647	1.129	2.193	1.189
Time of phosphorus application (P)						
2 weeks before sowing	45.78b	67.79	56.78	47.55	55.96	51.76
At sowing	46.90a	66.16	56.53	48.95	57.60	53.28
S.E±	0.359	2.083	1.041	0.714	1.387	0.752
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.18 100 Kernel Weight (g)

The effects of weed control method and time of phosphorus application on 100-kernel weight of groundnut varieties at Samaru and Minjibir in the 2018 and 2019 wet seasons are shown in Table 53. Generally, SAMNUT-22 produced heaviest 100-kernel weight in both years at Samaru and in 2019 at Minjibir and over time although this was similar to the value recorded over time at Minjibir. SAMNUT-23 consistently produced the least 100 kernel weight in both locations, years and over time. However, SAMNUT-23 was consistently similar in 100-kernel weight to SAMNUT-24 in Samaru and only in Minjibir in 2018 and 2019.

The effect of weed control method on 100-kernel weight of groundnut was significant at both locations and years. Black polythene mulch significantly higher 100-kernel weight in both locations, years and the mean, except at Samaru in 2019 when it was at a *par* with pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1}, 10 cm intra-row spacing and hoe weeding at 3 and 6 WAS. Weedy check consistently produced the lowest 100- kernel weight.

The time of phosphorus application had significantly affected on 100-kernel weight only at Samaru in 2018. Application of phosphorus at sowing resulted in significantly heavier 100-kernel weight than application at 2 weeks before sowing. There were no significant factor interaction effects on 100-kernel weight.

Table 53: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on 100 kernel weight (g) at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	100 kernel weight (g)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	55.09a	59.76a	57.42a	54.78b	58.66a	56.72a
SAMNUT- 23	45.95b	51.61b	48.80b	51.51b	53.02b	52.26b
SAMNUT -24	44.53b	49.98b	47.25b	62.53a	53.04b	57.98a
S.E±	0.832	1.225	0.756	1.339	1591	1.110
Weed control method (W)						
Weedy check	47.11b	51.44b	49.27b	50.14c	44.84b	47.49c
Black polythene mulch	48.08ab	58.39a	53.23a	57.85ab	58.90a	58.37ab
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	47.51ab	53.88b	50.70ab	53.43bc	55.74a	54.58b
Hoe-weeding at 3 and 6 WAS	50.66a	50.83b	50.75ab	58.68a	57.84a	58.26ab
Intra-row spacing (10 cm)	49.25ab	54.43b	51.84ab	61.26a	57.85a	59.55a
S.E.±	1.061	1.173	0.839	1.505	2.505	1.522
Time of phosphorus application (P)						
2 weeks before sowing	47.40b	54.55	50.98	54.93	54.31	54.62
At sowing	49.64a	53.04	51.34	57.61	55.78	56.68
S.E±	0.671	0.742	0.530	0.951	1.584	0.962
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.19 Haulm Yield (kg ha^{-1})

Table 54 shows the haulm yield of three groundnut varieties as affected by weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. Except in 2018 at Samaru when SAMNUT-23 was superior in haulm yield, SAMNUT-24 consistently produced more haulm yield when compare to other varieties at both locations, in both years and the over time. However, haulm yield in SAMNUT-22 was generally at a *par* with that of SAMNUT-23 over time in Samaru and at all times in Minjibir. Generally, the lowest haulm yields were obtained from either and/or both SAMNUT-22 and SAMNUT-23.

The effect of weed control method on groundnut haulm yield was significant in both locations and years. Black polythene mulch consistently gave the highest haulm yield in both locations, years and over time, except at Minjibir in 2018 when it gave lower haulm yield than the highest the hoe weeding at 3 and 6 WAS. Black polythene mulch gave the highest haulm yield though at a *par* with hoe weeding at 3 and 6 WAS at Samaru in 2018. Pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} had lower haulm yield, though comparable to 10 cm intra-row spacing at both locations, in both years and the mean. Weedy check produced the least haulm yield in 2019 at Samaru, in both years at Minjibir and the mean of both locations.

The time of phosphorus application had no significant effect on haulm yield in both locations, years and over time. The effects of factor interacting on haulm yield were significant only at Samaru in 2019.

The interaction of variety and weed control method significantly affected haulm yield only in 2019 at Samaru (Table 55). The use of black polythene mulch on SAMNUT-24 gave the

Table 54: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Haulm Yield (kg ha^{-1}) at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Haulm Yield (kg ha^{-1})					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	1399.6c	2483.3b	1931.4b	1640.7b	2127.8ab	1884.2b
SAMNUT- 23	1800.0a	2118.5c	1959.2b	1703.7b	2046.3b	1875.0b
SAMNUT -24	1570.3b	2781.5a	2175.9a	1840.7a	2361.1a	2100.9a
S.E$\pm$	26.83	76.37	38.80	25.88	85.59	44.68
Weed control method (W)						
Weedy check	1379.6b	1429.0d	1404.3d	1561.7d	1256.2d	1408.9d
Black polythene mulch	1756.1a	3.583.3a	2669.8a	1839.5b	3512.3a	2675.9a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	1524.6b	2163.6c	1844.1c	1691.3c	1716.0c	1703.7c
Hoe-weeding at 3 and 6 WAS	1709.8a	2963.0b	2336.4b	1950.6a	2657.4b	2304.0b
Intra-row spacing (10 cm)	1546.3b	2166.7c	1856.5c	1598.7cd	1750.0c	1674.3c
S.E.$\pm$	53.63	150.37	80.57	34.87	113.73	56.17
Time of phosphorus application (P)						
2 weeks before sowing	1612.3	2475.3	2043.8	1720.9	2109.9	1915.4
At sowing	1554.3	2446.9	2000.6	1735.8	2246.9	1991.3
S.E$\pm$	33.92	95.10	50.96	22.05	71.93	35.52
Interactions						
V x W	NS	*	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing. * = Significant at 5 %.

Table 55: Interaction Effect of Groundnut Variety and Weed Control Method on Haulm Yield (kg ha^{-1}) of Groundnut at Samaru during the 2019 wet season.

	Variety		
Weed control method	SAMNUT-22	SAMNUT-23	SAMNUT-24
Weedy check	1264h	1458gh	1491gh
Black Polythene mulch	2722ab	2454bc	2833a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	1630fgh	1958de	1944def
Hoe-weeding at 3 and 6 WAS	2292cd	2028de	2690ab
Intra-row spacing (10 cm)	1750efg	1898ef	1921def
SE±		231.0	

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

highest haulm yield which was at a *par* with its in SAMNUT-22. The least haulm yield was obtained from weedy check on all the three groundnut varieties.

4.20 Harvest Index (HI)

The HI of groundnut variety as influenced by weed control methods and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons is presented in Table 56. SAMNUT-24 generally had the higher HI in both locations, in both years and the mean although this was comparable to HI values from SAMNUT-23 both in 2019 at Samaru and over time at Minjibir. Also, SAMNUT-22 generally had the lowest HI values that were similar to that of SAMNUT-23 at Samaru, SAMNUT-24 in 2018 at Minjibir and SAMNUT-23 in 2019 at Minjibir.

The effect of weed control methods on HI was significant in both locations, years and over time. Black polythene mulch and hoe weeding at 3 and 6 WAS gave similar and values and these were higher than in the other weed control methods used at both locations, years and the over time. Although comparable with that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} in 2019 at Samaru and Minjibir in 2018 respectively and 10 cm intra-row spacing in 2019 at Minjibir and the mean. Weedy check had the least harvest index at both locations, years and over time.

The time of phosphorus application significantly affected on HI at Minjibir in 2019. Application of phosphorus at sowing had significantly higher HI than phosphorus application at 2 weeks before sowing. There were no significant factor interaction effects on the HI of groundnut.

Table 56: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Harvest Index at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Harvest Index					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	57.0b	55.4b	56.25b	52.3b	64.8b	58.62b
SAMNUT- 23	61.9b	64.3ab	63.16b	70.2a	61.4b	65.84a
SAMNUT -24	75.2a	75.5a	75.39a	53.5b	81.8a	67.68a
S.E±	3.119	5.577	3.652	1.799	4.348	2.303
Weed control method (W)						
Weedy check	38.42c	37.60c	38.01d	53.71b	55.49c	54.60c
Black polythene mulch	78.28a	77.38a	77.83ab	64.71a	70.15b	67.43ab
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	63.70b	71.97ab	67.84b	67.32a	49.51c	58.41bc
Hoe-weeding at 3 and 6 WAS	89.33a	83.89a	86.61a	51.91b	89.34a	70.62a
Intra-row spacing (10 cm)	54.01b	54.76bc	54.38c	55.88b	82.45ab	69.16a
S.E.±	4.207	6.160	4.048	2.355	4.855	3.078
Time of phosphorus application (P)						
2 weeks before sowing	61.87	66.65	64.26	59.59	64.39b	61.99
At sowing	67.63	63.59	65.61	57.82	74.39a	66.10
S.E±	2.661	3.896	2.560	1.489	3.070	1.946
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

4.21 Shelling Percentage

Table 57 shows the shelling percentage of three varieties of groundnut as influenced by weed control methods and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. Except in 2018 at Samaru, SAMNUT-24 produced significantly higher shelling percentage than the other varieties, although this was similar to in SAMNUT-22 over time at Samaru and SAMNUT-23 in 2018 at Minjibir. SAMNUT-23 consistently produced the least shelling percentage at all times, except in 2018 at both locations when it was at a *par* with SAMNUT-22. The lower shelling percentage recorded from SAMNUT-23 were also at a *par* with that of SAMNUT-22 at Minjibir in both years and over time.

Weed management method significantly affected shelling percentage of groundnut varieties in both locations, years and over time. Black polythene significantly produced higher shelling percentage in 2019 and the combined at Samaru and in 2018 and the combined at Minjibir. It was though statistically same with that of pendimethalin at 1.5 kg a.i ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i ha^{-1} and weedy check at Samaru, hoe weeding at 3 and 6 WAS at Minjibir in 2019 and the combined year.

Time of phosphorus application generally had no significant effect on shelling percentage of groundnut. Generally, there was no significant factors interaction on shelling percentage.

4.22 Net Farm Income (₦)

Table 58 shows the Net Farm Income of three groundnut varieties as affected by weed control method and time of phosphorus application at Samaru and Minjibir during the 2018 and 2019 wet seasons. SAMNUT-24 significantly and consistently had the highest value for Net Farm Income in both locations, in both years and the average than the other groundnut varieties.

Table 57: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Shelling Percentage at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Shelling Percentage (%)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	56.87a	67.95b	62.41a	51.58b	62.17b	56.88b
SAMNUT- 23	56.55a	57.84c	57.19b	54.61ab	58.97b	56.79b
SAMNUT -24	51.11b	74.50a	62.81a	60.64a	66.61a	63.62a
S.E±	1.857	1.651	1.170	2.367	1.478	1.464
Weed control method (W)						
Weedy check	56.32ab	66.83b	61.58ab	37.82c	61.13abc	49.48c
Black polythene mulch	49.28b	84.32a	66.80a	69.36a	58.54c	63.95a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	60.10a	48.29c	54.200c	58.33b	65.96ab	62.15ab
Hoe-weeding at 3 and 6 WAS	53.02ab	67.26b	60.14b	58.51b	67.08a	62.83a
Intra-row spacing (10 cm)	55.48ab	67.11b	61.30ab	53.95b	60.20bc	57.08b
S.E.±	2.428	2.364	1.884	3.268	1.930	1.753
Time of phosphorus application (P)						
2 weeks before sowing	53.23	67.71	60.47	56.53	63.06	59.80
At sowing	56.46	65.81	61.13	54.69	62.10	58.39
S.E±	1.535	1.495	1.191	1.067	1.221	1.109
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

Table 58: Effect of Groundnut Variety, Weed Management Strategies and Time of Phosphorus Application on Net Farm Income (₦) at Samaru and Minjibir during the 2018 and 2019 wet seasons.

	Net Farm Income (₦)					
	Samaru			Minjibir		
Treatments	2018	2019	Mean	2018	2019	Mean
Variety (V)						
SAMNUT- 22	468422b	642990b	206208b	342668b	628386b	210044b
SAMNUT- 23	516961b	661481b	239722b	357539b	688645b	248102b
SAMNUT -24	587417a	848970a	368695a	398424a	821507a	334730a
S.E±	21111.7	22086.9	14617.5	5537.6	29443.2	15924.6
Weed control method (W)						
Weedy check	468351c	449010d	109346c	353622b	357579d	79543c
Black polythene mulch	557823ab	1024620a	441888a	360546b	1140328a	475406a
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	535580abc	595594c	216049b	351399b	514940c	158139b
Hoe-weeding at 3 and 6 WAS	580384a	873049b	376971a	411681a	989730b	425880a
Intra-row spacing (10 cm)	479196c	646795c	213455b	353804b	561653c	182492b
S.E.±	25944.3	42804.2	26387.5	8669.6	34010.4	16835.6
Time of phosphorus application (P)						
2 weeks before sowing	521917	713448	268019	364769	702464	258503
At sowing	526616	722180	275064	367652	723228	270081
S.E±	16408.6	27071.7	16688.6	5483.1	21509.8	10647.8
Interactions						
V x W	NS	NS	NS	NS	NS	NS
V x P	NS	NS	NS	NS	NS	NS
W x P	NS	NS	NS	NS	NS	NS
V x W x P	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) within the same treatment group /column are not significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT). NS = Not Significant. WAS = Weeks After Sowing.

The effect of weed control method on Net Farm Income of groundnut was significant at both locations, in both years and over time. Black polythene mulch had significantly the highest value for Net Farm Income in both years at Samaru, in 2019 at Minjibir and the mean of both locations. However, black polythene mulch was similar to hoe weeding at 3 and 6 WAS in 2018 at Samaru and the mean of both locations. Also hoe weeding at 3 and 6 WAS had higher value for Net Farm Income of groundnut at Minjibir in 2018 than other weed control methods. Weedy check had the lowest value for Net Farm Income of groundnut in both locations, in both years and over time.

Time of phosphorus application had no significant effect on Net Farm Income of groundnut in both locations, in both years and over time. There were no significant interaction effects among the factors on Net Farm Income of groundnut.

4.23 Correlation Coefficient Matrix between Pod yield and some Weed, Growth and Yield Characters of Groundnuts

The correlation coefficient between pod yield, some weed, growth and yield characters of three groundnut varieties at Samaru are indicated in Table 59 and 60. At Samaru in 2018, pod yield had positive and highly significant relationship with canopy spread (r= 0.392**). The correlation between pod yield and weed control efficiency was positive and significant (r = 0.322*). Relationship between pod yield and weed dry weight was negative and significant. Pod yield was negative and not significantly correlated with leaf area index and crop growth rate. Pod yield had positive but not significant with harvest index and haulm yield.

In 2019 at Samaru, pod yield had positive and significant relationship with weed control efficiency. The correlation between pod yield and weed dry weight was negative and highly

Table 59: Correlation of Pod Yield and some Weed, Growth and Yield Characters of Groundnut at Samaru during the 2018 wet season.

	Pod yield (kg ha^{-1})	Weed control efficiency (%)	Weed dry weight (*g m-^{2}*)	Canopy spread (cm)	Leaf area index	Crop growth rate (g m^{-2} wk^{1})	100 kernel weight (g)	Shelling percent	Harvest Index	Haulm yield (kg ha^{-1})
Pod yield (kg ha^{-1})	1.000									
Weed control efficiency (%)	0.322*	1.000								
Weed dry weight (*g m-^{2}*)	-0.275*	-0.885**	1.000							
Canopy spread (cm)	0.392**	0.499**	-0.469**	1.000						
Leaf area index	-0.006	0.402**	0.445**	0.141	1.000					
Crop growth rate (g m^{-2} wk^{1})	-0.031	0.293	-0.283	0.050	0.118	1.000				
100 kernel weight (g)	-0.057	0.088	-0.097	0.065	0.209	-0.149	1.000			
Shelling percent	-0.247	-0.326	0.310	-0.220	-0.070	-0.109	0.119	1.000		
Harvest index	0.202	0.675**	-0.578**	0.395**	0.168	0.172	-0.061	-0.226	1.000	
Haulm yield (kg ha^{-1})	0.110	0.429**	-0.289	0.198	0.076	0.287	-0.213	-0.290	0.338	1.000

*=Significant at 5% level of probability, **= Significant at 1% level of probability.

Table 60: Correlation of Pod Yield and some Weed, Growth and Yield Character of Groundnut at Samaru during the 2019 wet season.

	Pod yield (kg ha^{-1})	Weed control efficiency (%)	Weed dry weight (*g m-^{2}*)	Canopy spread (cm)	Leaf area index	Crop growth rate (g m $^{-2}$ wk^{1})	100 kernel weight (g)	Shelling percent	Harvest Index	Haulm yield (kg ha^{-1})
Pod yield (kg ha^{-1})	1.000									
Weed control efficiency (%)	0.334*	1.000								
Weed dry weight (*g m-^{2}*)	-0.424**	-0.828*	1.000							
Canopy spread (cm)	0.197	0.233	-0.196	1.000						
Leaf area index	0.311*	0.263	-0.443**	0.059	1.000					
Crop growth rate (g m $^{-2}$ wk^{1})	0.123	0.208	-0.251	-0.017	-0.012	1.000				
100 kernel weight (g)	0.052	0.221	-0.127	-0.010	-0.128	0.036	1.000			
Shelling percent	0.448**	0.596**	-0.665**	0.154	0.438**	0.111	0.241	1.000		
Harvest index	0.354*	0.406**	-0.424**	0.115	0.332	0.089	-0.048	0.348*	1.000	
Haulm yield (kg ha^{-1})	0.533**	0.556**	-0.599**	0.121	0.355*	0.019	0.098	0.653**	0.471**	1.000

*=Significant at 5% level of probability, **= Significant at 1% level of probability.

significant (-0.424**). Relationship between groundnut pod yield and leaf area index was positive and significant (r = 0.311*). Pod yield had positive and highly significant correlation with shelling percentage and haulms yield, except for harvest index were the relationship was only positive (r = 0.354*).

Table 61 and 62 shows the relationship between pod yield, some weed, growth and yield characters of three groundnut varieties at Minjibir. In 2018 at Minjibir, pod yield had positive and highly significant relationship with weed control efficiency, canopy spread and leaf area index. The relationship between pod yield and weed dry weight was negative and highly significant (r = - 0.432**). The correlation between pod yield and other yield parameter was positive except for shelling percentage that correlated negatively and not significant. But haulm yield correlated positively and highly significant (r= 0.701**).

In 2019 at Minjibir, the correlation between pod yield and weed control efficiency was positive and not significant. Pod yield had negative and highly significant relationships with weed dry weight. The relationships between pod yield and leaf area index was positive and significant (r = 0.309*). The correlation between pod yield, harvest index and haulm yield were both positive and highly significant. But relationship with shelling percentage was negative and not significant.

Table 61: Correlation of Pod Yield and some Weed, Growth and Yield Character of Groundnut at Minjibir during the 2018 wet season.

	Pod yield (kg ha^{-1})	Weed control efficiency (%)	Weed dry weight (*g m-^{2}*)	Canopy spread (cm)	Leaf area index	Crop growth rate (g m^{-2} wk^{1})	100 kernel weight (g)	Shelling percent	Harvest Index	Haulm yield (kg ha^{-1})
Pod yield (kg ha^{-1})	1.000									
Weed control efficiency (%)	0.409**	1.000								
Weed dry weight (*g m-^{2}*)	-0.432**	-0.858**	1.000							
Canopy spread (cm)	0.724**	0.375*	-0.387*	1.000						
Leaf area index	0.415**	0.446	0.386	0.433**	1.000					
Crop growth rate (g m^{-2} wk^{1})	0.048	0.031	-0.074	0.156	0.056	1.000				
100 kernel weight (g)	0.122	0.281*	-0.174	0.182	0.311*	0.141	1.000			
Shelling percent	-0.012	0.448**	-0.407**	0.109	0.198	0.161	0.410**	1.000		
Harvest index	0.012	-0.362*	0.312	0.256	-0.434**	-0.152	-0.329*	-0.216	1.000	
Haulm yield (kg ha^{-1})	0.701**	0.616**	-0.565**	0.684**	0.499**	0.024	0.185	0.136	-0.524**	1.000

*=Significant at 5% level of probability, **= Significant at 1% level of probability.

Table 62: Correlation of Pod Yield and some Weed, Growth and Yield Character of Groundnut at Minjibir during the 2019 wet season.

	Pod yield (kg ha^{-1})	Weed control efficiency (%)	Weed dry weight (*g m-^{2}*)	Canopy spread (cm)	Leaf area index	Crop growth rate (g m $^{-2}$ wk^{1})	100 kernel weight (g)	Shelling percent	Harvest Index	Haulm yield (kg ha^{-1})
Pod yield (kg ha^{-1})	1.000									
Weed control efficiency (%)	0.087	1.000								
Weed dry weight (*g m-^{2}*)	-0.517**	0.085	1.000							
Canopy spread (cm)	0.261	-0.007	-0.112	1.000						
Leaf area index	0.309*	0.109	-0.294*	0.075	1.000					
Crop growth rate (g m $^{-2}$ wk^{1})	0.319	-0.030	-0.113	0.194	0.107	1.000				
100 kernel weight (g)	0.167	0.326*	-0.128	0.095	0.173	-0.011	1.000			
Shelling percent	-0.183	0.166	0.181	0.116	0.079	-0.145	0.076	1.000		
Harvest index	0.462**	0.171	-0.241	0.197	0.274	0.116	0.285*	0.172	1.000	
Haulm yield (kg ha^{-1})	0.813**	0.050	-0.455**	0.299*	0.386*	0.417**	0.385*	-0.091	0.413**	1.000

*=Significant at 5% level of probability, **= Significant at 1% level of probability.

4.24 Profitability Analysis

The profitability analysis of groundnut varieties and its response to weed control methods and time of phosphorus application at Samaru in 2018 and 2019 wet seasons are presented in Tables 63 and 64. At Samaru in both years the fixed cost of producing one hectare of groundnut was ₦63,000. In 2018, the use of black polythene mulch and applying phosphorus at sowing to SAMNUT-24 recorded the highest Net Farm Income of ₦ 809,089 followed by SAMNUT-24, hoe weeding at 3 and 6 WAS and applying phosphorus at 2 weeks before sowing, SAMNUT-24, hoe weeding at 3 and 6 WAS application of phosphorus at sowing, SAMNUT-24, pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluzifop-P-butyl at 1.0 kg a.i. ha^{-1} and application of phosphorus at sowing with respective Net Farm Income of ₦ 666,041, ₦ 648,786 and ₦ 648,375. Application of pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluzifop-P-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS and applying phosphorus at 2 weeks before sowing to SAMNUT-22 recorded the least Net Farm Income of ₦ 431,644. Also in 2019 SAMNUT-24, black polythene mulch and applying phosphorus at sowing recorded the highest value for Net Farm Income of ₦ 1,405,643 followed by SAMNUT-24, hoe weeding at 3 and 6 WAS and applying phosphorus at 2 weeks before sowing recorded value for Net Farm Income of ₦ 1,252,596. SAMNUT-23, weedy check and applying phosphorus at sowing recorded the least values for Net Farm Income of ₦ 443,755.

Table 63: Partial Economic Analysis of Groundnut Varieties as influenced by Weed Management Strategies and Time of Phosphorus Application at Samaru during sthe 2018 wet season.

Treatment	Pod yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Revenue from pod (₦)	Revenue from fodder (₦)	Total revenue (₦)	Total fixed cost (₦)	Total variable cost (₦)	Total cost (₦)	Net farm income (₦)
V1W1P1	1444	1185	384104	157630	541734	63000	28600	91600	450,134
V2W1P1	1342	1741	356972	231519	588491	63000	28600	91600	496,891
V3W1P1	1477	1407	392990	187185	580176	63000	28600	91600	488,576
V1W2P1	1529	1630	406606	216741	623346	63000	76600	139600	483,746
V2W2P1	1752	2241	465909	298019	763927	63000	76600	139600	624,327
V3W2P1	2114	1611	562196	214278	776474	63000	76600	139600	636,874
V1W3P1	1365	1315	363174	174870	538044	63000	43400	106400	431,644
V2W3P1	1348	1759	358652	233981	592633	63000	43400	106400	486,233
V3W3P1	1588	1500	422349	199500	621849	63000	43400	106400	515,449
V1W4P1	1526	1519	405852	201963	607815	63000	43600	106600	501,215
V2W4P1	1647	2056	438072	273389	711461	63000	43600	106600	604,861
V3W4P1	2090	1630	555901	216741	772641	63000	43600	106600	666,041
V1W5P1	1420	1278	377651	169944	547595	63000	34600	97600	449,995
V2W5P1	1387	1759	368942	233981	602923	63000	34600	97600	505,323
V3W5P1	1420	1556	377769	206889	584658	63000	34600	97600	487,058
V1W1P2	1467	1185	390311	157630	547940	63000	28600	91600	456,340
V2W1P2	1309	1407	348263	187185	535448	63000	28600	91600	443,848
V3W1P2	1450	1352	385725	179796	565521	63000	28600	91600	473,921
V1W2P2	1512	1481	402256	197037	599293	63000	76600	139600	459,693
V2W2P2	1562	1889	415576	251222	666798	63000	76600	139600	527,198

V3W2P2	2770	1593	736820	211869	948689	63000	76600	139600	809,089
V1W3P2	1467	1389	390163	184722	574885	63000	43400	106400	468,485
V2W3P2	1369	1593	364124	211815	575939	63000	43400	106400	469,539
V3W3P2	1995	1685	530670	224105	754775	63000	43400	106400	648,375
V1W4P2	1701	1500	452372	199500	651872	63000	43600	106600	545,272
V2W4P2	1443	1796	383818	238907	622726	63000	43600	106600	516,126
V3W4P2	1960	1759	521404	233981	755386	63000	43600	106600	648,786
V1W5P2	1354	1315	360179	174870	535049	63000	34600	97600	437,449
V2W5P2	1349	1759	358735	233981	592717	63000	34600	97600	495,117
V3W5P2	1442	1611	383557	214278	597835	63000	34600	97600	500,235

V1= SAMNUT-22, V2 =SAMNUT-23, V3= SAMNUT-24 W1 =Weedy check, W2 = Black polythene mulch, W3= Pendimethalin at 1.5 kg a.i. ha^{-1} fb. Fluazifop-p- butyl at 1.0 a.i. ha^{-1} at 3 WAS, W4= Hoe weeding at 3 and 6 WAS, W5= 10 cm intra-row spacing , P1= 2 weeks before sowing, P2= At sowing.

Table 64: Partial Economic Analysis of Groundnut Varieties as influenced by Weed Management Strategies and Time of Phosphorus Application at Samaru during the 2019 wet season.

Treatment	Pod yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Revenue from pod (₦)	Revenue from fodder(₦)	Total revenue (₦)	Total fixed cost (₦)	Total variable cost (₦)	Total cost (₦)	Net farm income (₦)
V1W1P1	1578	1463	419758	194574	614332	63000	28600	91600	522,732
V2W1P1	1617	1333	430156	177333	607490	63000	28600	91600	515,890
V3W1P1	1587	1685	422043	224130	646173	63000	28600	91600	554,573
V1W2P1	3054	3519	812285	467963	1280248	63000	76600	139600	1,140,648
V2W2P1	2474	3278	658212	435944	1094157	63000	76600	139600	954,557
V3W2P1	2930	3704	779400	492593	1271992	63000	76600	139600	1,132,392
V1W3P1	1665	1815	442811	241370	684182	63000	43400	106400	577,782
V2W3P1	1732	2667	460801	354667	815467	63000	43400	106400	709,067
V3W3P1	1976	2389	525724	317722	843447	63000	43400	106400	737,047
V1W4P1	2039	3204	542340	426093	968432	63000	43600	106600	861,832
V2W4P1	2411	2204	641193	293093	934286	63000	43600	106600	827,686
V3W4P1	3063	4093	814881	544315	1359196	63000	43600	106600	1,252,596
V1W5P1	1817	2333	483386	310333	793719	63000	34600	97600	696,119
V2W5P1	1784	1315	474539	174870	649409	63000	34600	97600	551,809
V2W5P1	2550	2130	678344	283241	961585	63000	34600	97600	863,985
V1W1P2	1458	1222	387872	162556	550428	63000	28600	91600	458,828
V2W1P2	1337	1352	355558	179796	535355	63000	28600	91600	443,755
V3W1P2	2131	1519	566718	201963	768681	63000	28600	91600	677,081
V1W2P2	2019	4259	537143	566481	1103624	63000	76600	139600	964,024
V2W2P2	3191	2407	848673	320185	1168858	63000	76600	139600	1,029,258

V3W2P2	3643	4333	968910	576333	1545243	63000	76600	139600	1,405,643
V1W3P2	1485	2000	394907	266000	660907	63000	43400	106400	554,507
V2W3P2	2133	1815	567467	241370	808837	63000	43400	106400	702,437
V3W3P2	2152	2296	572516	305407	877923	63000	43400	106400	771,523
V1W4P2	2251	2944	598800	391611	990412	63000	43600	106600	883,812
V2W4P2	1947	2056	518010	273389	791399	63000	43600	106600	684,799
V3W4P2	3297	3278	877027	435944	1312971	63000	43600	106600	1,206,371
V1W5P2	1464	2074	389365	275852	665217	63000	34600	97600	567,617
V2W5P2	2722	2759	724170	366981	1091152	63000	34600	97600	993,552
V3W5P2	1753	2389	466367	317722	784089	63000	34600	97600	686,489

V1= SAMNUT-22, V2 =SAMNUT-23, V3= SAMNUT-24 W1 =Weedy check, W2 = Black polythene mulch, W3= Pendimethalin at 1.5 kg a.i. ha^{-1} fb. Fluazifop-p- butyl at 1.0 a.i. ha^{-1} at 3 WAS, W4= Hoe weeding at 3 and 6 WAS, W5= 10 cm intra-row spacing , P1= 2 weeks before sowing, P2= At sowing.

The profitability analysis of groundnut varieties and its response to weed control methods and time of phosphorus application at Minjibir in 2018 and 2019 wet season are presented in Tables 65 and Table 66. In 2018 and 2019 at Minjibir the fixed cost of producing one hectare of groundnut was N63,000. In 2018, the use of hoe weeding at 3 and 6 WAS and applying phosphorus at 2 weeks before sowing to SAMNUT-24 recorded the highest value for Net Farm Income of ₦ 595,788 followed by SAMNUT-24, black polythene mulch and applying phosphorus at sowing and the use of SAMNUT-23, hoe weeding at 3 and 6 WAS and application of phosphorus at 2 Weeks before sowing recorded values for Net Farm Income of ₦ 569,258 and 556,405 respectively. While the use of pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop–P- butyl at 1.0 a.i. ha^{-1} at 3 WAS and applying phosphorus at 2 weeks before sowing to SAMNUT-23 recorded the lowest value for Net Farm Income of ₦ 446,437. Also in 2019, SAMNUT-24, black polythene mulch and application of phosphorus at sowing recorded the highest value for Net Farm Income of ₦ 1,434,036 followed by SAMNUT-23, black polythene mulch and applying phosphorus at sowing and SAMNUT-22, black polythene mulch and applying phosphorus at 2 weeks sowing recorded values for Net Farm Income of ₦1258082 and ₦1,231,384 respectively. While SAMNUT-23, weedy check and applying phosphorus at 2 weeks before sowing recorded the least value for Net Farm Income of ₦ 325,330.

Table 65: Partial Economic Analysis of Groundnut Varieties as influenced by Weed Management Strategies and Time of Phosphorus Application at Minjibir during the 2018 wet season.

Treatment	Pod yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Revenue from pod (₦)	Revenue from fodder(₦)	Total revenue (₦)	Total fixed cost (₦)	Total variable cost (₦)	Total cost (₦)	Net farm income (₦)
V1W1P1	1358	1519	361267	201963	563230	63000	28600	91600	471,630
V2W1P1	1337	1500	355701	199500	555201	63000	28600	91600	463,601
V3W1P1	1450	1593	385749	211815	597564	63000	28600	91600	505,964
V1W2P1	1413	1815	375799	241370	617169	63000	76600	139600	477,569
V2W2P1	1456	1741	387375	231519	618893	63000	76600	139600	479,293
V3W2P1	1535	1833	408310	243789	652099	63000	76600	139600	512,499
V1W3P1	1332	1593	354223	211815	566038	63000	43400	106400	459,638
V2W3P1	1291	1574	343485	209352	552837	63000	43400	106400	446,437
V3W3P1	1408	1852	374469	246296	620765	63000	43400	106400	514,365
V1W4P1	1432	1926	380971	256148	637119	63000	43600	106600	530,519
V2W4P1	1502	1981	399532	263473	663005	63000	43600	106600	556,405
V3W4P1	1576	2130	419147	283241	702388	63000	43600	106600	595,788
V1W5P1	1329	1444	353632	192111	545743	63000	34600	97600	448,143
V2W5P1	1403	1593	373090	211815	584904	63000	34600	97600	487,304
V3W5P1	1446	1593	384715	211815	596530	63000	34600	97600	498,930
V1W1P2	1350	1500	359100	199500	558600	63000	28600	91600	467,000
V2W1P2	1369	1556	364026	206889	570915	63000	28600	91600	479,315
V3W1P2	1493	1704	397227	226593	623819	63000	28600	91600	532,219

V1W2P2	1390	1704	369691	226593	596283	63000	76600	139600	456,683
V2W2P2	1466	1852	390035	246296	636331	63000	76600	139600	496,731
V3W2P2	1536	1944	408576	258552	667128	63000	34600	97600	569,258
V1W3P2	1373	1593	365159	211815	576974	63000	43400	106400	470,574
V2W3P2	1381	1704	367425	226593	594017	63000	43400	106400	487,617
V3W3P2	1467	1833	390330	243833	634164	63000	43400	106400	527,764
V1W4P2	1433	1778	381217	236444	617662	63000	43600	106600	511,062
V2W4P2	1457	1926	387621	256148	643769	63000	43600	106600	537,169
V3W4P2	1435	1944	381661	258611	640272	63000	43600	106600	533,672
V1W5P2	1342	1537	357031	204426	561457	63000	34600	97600	463,857
V2W5P2	1330	1593	353829	211815	565644	63000	34600	97600	468,044
V3W5P2	1506	2000	400596	266000	666596	63000	76600	139600	526,996

V1= SAMNUT-22, V2 =SAMNUT-23, V3= SAMNUT-24 W1 =Weedy check, W2 = Black polythene mulch, W3= Pendimethalin at 1.5 kg a.i. ha^{-1} fb. Fluazifop-p- butyl at 1.0 a.i. ha^{-1} at 3 WAS, W4= Hoe weeding at 3 and 6 WAS, W5= 10 cm intra-row spacing , P1= 2 weeks before sowing, P2= At sowing.

Table 66: Partial Economic Analysis of Groundnut Varieties as influenced by Weed Management Strategies and Time of Phosphorus Application at Minjibir during the 2019 wet season.

Treatment	Pod yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Revenue from pod (₦)	Revenue from fodder(₦)	Total revenue (₦)	Total fixed cost (₦)	Total variable cost (₦)	Total cost (₦)	Net farm income (₦)
V1W1P1	1266	1352	336736	179796	516533	63000	28600	91600	424,933
V2W1P1	993	1148	264227	152704	416930	63000	28600	91600	325,330
V3W1P1	1221	1296	324914	172407	497321	63000	28600	91600	405,721
V1W2P1	2421	3370	644114	448259	1092373	63000	76600	139600	952,773
V2W2P1	3413	3481	907947	463037	1370984	63000	76600	139600	1,231,384
V3W2P1	3333	3333	886568	443333	1329901	63000	76600	139600	1,190,301
V1W3P1	1214	1352	322894	179796	502691	63000	43400	106400	396,291
V2W3P1	1492	1648	396931	219204	616135	63000	43400	106400	509,735
V3W3P1	2266	2315	602786	307870	910656	63000	43400	106400	804,256
V1W4P1	2765	2463	735441	327574	1063015	63000	43600	106600	956,415
V2W4P1	2716	2130	722338	283241	1005579	63000	43600	106600	898,979
V3W4P1	3407	2981	906321	396537	1302858	63000	43600	106600	1,196,258
V1W5P1	1483	1852	394370	246296	640666	63000	34600	97600	543,066
V2W5P1	1400	1259	372400	167481	539881	63000	34600	97600	442,281
V3W5P1	2008	1667	534167	221667	755834	63000	34600	97600	658,234
V1W1P2	1230	1148	327131	152704	479834	63000	28600	91600	388,234
V2W1P2	1065	1204	283389	160093	443481	63000	28600	91600	351,881
V3W1P2	1187	1389	315850	184722	500573	63000	28600	91600	408,973

V1W2P2	2364	3352	628794	445796	1074591	63000	76600	139600	934,991
V2W2P2	3412	3685	907553	490130	1397682	63000	76600	139600	1,258,082
V3W2P2	3990	3852	1061340	512296	1573636	63000	76600	139600	1,434,036
V1W3P2	1337	1593	355603	211815	567417	63000	43400	106400	461,017
V2W3P2	1546	1500	411364	199500	610864	63000	43400	106400	504,464
V3W3P2	1611	1889	428654	251222	679876	63000	43400	106400	573,476
V1W4P2	2684	3259	713816	433481	1147297	63000	43600	106600	1,040,697
V2W4P2	2582	2148	686871	285704	972575	63000	43600	106600	865,975
V3W4P2	3204	2963	852185	394074	1246259	63000	43600	106600	1,139,659
V1W5P2	1296	1537	344618	204426	549044	63000	34600	97600	451,444
V2W5P2	2111	2259	561457	300481	861939	63000	34600	97600	764,339
V3W5P2	1923	1926	511607	256148	767755	63000	34600	97600	670,155

V1= SAMNUT-22, V2 =SAMNUT-23, V3= SAMNUT-24 W1 =Weedy check, W2 = Black polythene mulch, W3= Pendimethalin at 1.5 kg a.i. ha^{-1} fb. Fluazifop-p- butyl at 1.0 a.i. ha^{-1} at 3 WAS, W4= Hoe weeding at 3 and 6 WAS, W5= 10 cm intra-row spacing , P1= 2 weeks before sowing, P2= At sowing.

CHAPTER FIVE

5.0 DISCUSSION

5.1 General Discussion

The results from the experiments showed that groundnut yield varied between Samaru and Minjibir. The general performance of the groundnut yield characters; like pod yield, kernel yield, 100-seed weight and haulm yield was higher in 2019 at Samaru and Minjibir than in 2018 at both locations probably due to amount of rainfall and temperature received in 2019 (Appendices I and II), coupled with an ideal textural class of the soils in the experimental sites that is sandy loam with neutral pH and moderate amount of available phosphorus in the soils in both locations (Table 1 and 2) indeed facilitated the early root establishment of the crop which eventually play's a significant role in the growth and developmental stages of the crop pod filling inclusive.

Weed infestation was lowest at Minjibir in 2018 only than in both years at Samaru. Probably because Samaru belongs to northern Guinea ecological zone of Nigeria and therefore, received more rainfall than Minjibir, as a result these favour the thriving population of several weed species to deposit more seed bank in the soils due to favourable weather conditions in both locations. Time of phosphorus application did not affect the crop performance at both locations and the years. This could be due to the fact that available phosphorus in the respective experimental sites was adequate for groundnut production.

5.2 Effect of Weed Control Methods on Weeds

Adopting a comprehensive weed control package will indeed have a lasting effect on addressing the menace of weeds in groundnut fields, thereby enabling the crop to maximize available growth resources which in turn may translate to better growth and yield of groundnut as observed in the current study. Similarly, previous researchers had posited that no single method of weed control can successfully smother various weed species (Olayinka *et al.,* 2009; Shanwad *et al.*, 2011; Ianovici, 2011).

Among the weed control method employed in these trials, black polythene mulch and hoe weeding at 3 and 6 WAS significantly lowered weed dry weight and effectively controlled weeds, thereby resulting in better yield (pod) as compared to weedy check. This is in conformity with the reports of Rilwanu (2019) who demonstrated that two hoe weeding at 3 and 6 WAS had significantly low weed cover score and weed dry weight. This could be due to the fact that hoe weeding, if done properly, ensures complete weed removal or desiccation of some susceptible weed seed species.

This is because the black polythene mulch has the ability to trap heat (soil solarization) underneath the mulched material thereby triggering the weed seeds to germinate as a result of intense solar heat.

5.3 Response of Groundnut Varieties

Crop varieties are known to exhibit variation in their growth and yield parameters due to differences in their genetic makeup and gene interaction with the environment (moisture, sunshine hours and soil fertility) as well as good agronomic maneuver. So this is not different from the results obtain in the present study. The superiority of SAMNUT-24 (extra-early maturing variety) over SAMNUT-22 (medium maturing variety) and SAMNUT-23 (early maturing variety) in most of the growth (stand count, plant height, canopy spread and earlier days to 50 percent flowering), yield (pod and haulm) and yield components (seed yield, shelling percentage and harvest index) characters, could be as a result of SAMNUT-24 was bred as dual purpose (pod and haulm yield) so that gives it an edge over the other two varieties used in term of accumulation more dry matter for subsequent yield production.

Under normal circumstances, as a result of longer leaf area duration of the early and medium maturing varieties, more dry matter was expected to be generated and therefore, better growth and yield from the early and medium maturing variety. However, one remarkable thing observed contrary to what was expected is the superiority of an extra-early variety over the early and medium variety in terms of the growth and yield parameters measured. This could be due to the genetics of the variety was bred as a dual purpose (haulm and pod yield).

It could probably be as a result of the ability of the extra-early maturing variety to withstand both weed pressure and different weed control strategies employed that includes tolerance to herbicide used, thus giving the extra-early maturing SAMNUT-24 variety an edge over SAMNUT-22 and SAMNUT-23 in terms of growth and yield parameters such as plant height, canopy spread, crop growth rates nodules count, leaf area index, earlier days to 50 percent flowering, shelling percentage, pod and haulms yield among others.

The reasons for these variation and inconsistencies that manifested among the tested groundnut varieties in terms of growth and yield characters could be as a result of the differences in genetic makeup of the three varieties in response to environment. This is in accordance with the finding of Ibrahim *et al.*(2014) who reported that crop differ in their ability to assimilate photosynthates and partitioning of these assimilates to growth and yield characters of the crop.

Also, the earlier flowering of SAMNUT-24 relatives to the varieties others further reinforced it as an early maturing variety. Similar, finding was reported by Roland (2016) who also noted that SAMNUT -24 proves to be consistently taller than the other varieties and recorded more mature pods plant^{-1} and highest harvest index value. The superiority of SAMNUT-24 in this regards could be attributed it to is genetically a Spanish type with erect bunch, and few branches that give it open appearance. The late flowering observed in SAMNUT-22 relative to SAMNUT-23 and SAMNUT-24 is in line with its genetic attribute as a medium maturity and as such is expected to flower later than two other earlier maturing varieties.

The heavier 100-seed weight recorded by SAMNUT-22 could be due to its genetic makeup and large seed size. This finding is in consonance with that reported earlier by Roland (2016) who found that the superiority of SAMNUT -22 and SAMNUT -21 could be attributed to their growth habit (intermediate growth habit), that resulted in better light interception leading to higher biomass production that invariably led to larger seed size because of the longer duration of grain filling processes than other varieties used.

5.4 Effect of Groundnut Variety on Weeds

The rapid growth and development recorded in respect of plant height and canopy spread exhibited by SAMNUT-24 helped greatly in smothering weeds population, due to the dense canopy it formed compared to SAMNUT-22 and SAMNUT-23 varieties that had low weed dry weight and higher values for weed control efficiency. The variation recorded among the groundnut varieties in this study is also in line with the findings of Ibrahim (2015), who earlier reported that the heavy branching characteristics in SAMNUT-11 gave it some advantage in weed suppression as evidenced by low weed cover score and high weed control efficiency when compared to poor weed suppression in plots grown to both SAMNUT-23 and SAMNUT-22.

Similarly, this study reported low weed cover score and crop injury score in plots grown to SAMNUT-24 compared to higher values of these weed parameters in plot of SAMNUT-22 and SAMNUT-23. The weed suppressing ability of SAMNUT-24 could be due to the semi-erect growth habit and extra early maturity attribute, so it was able to successfully withstand intensive competition with weeds and therefore, suppressed weeds faster because of its faster growth rate when compared to the other two varieties.

The role played by leaf are index, crop growth rate and relative growth rate in terms of accelerated accumulation of dry matter recorded on plots grown to SAMNUT-24 variety as indicated by this study, play a significant role in decreasing weed population, thus resulting to minimum competition by weeds for growth factors with SAMNUT-24 as comparable to the other two varieties. Also, Haruna *et al.* (2019) who revealed that Bambara groundnut variety with white coat and brown strip had least crop injury score than variety with white coat white eye and white coat black strip. The reason for this variation could be the competing ability of Bambara groundnut variety used in weeds suppression as evidenced by lower weed dry weight and weed cover score.

Early dominance exhibited by SAMNUT-24, in terms of intra-specific and inter-specific competition with weeds, pave way for mass production of nodules in the root zone of the groundnut plant as evidenced by nodule count in this study; giving it additional source of tapping nutrients via nitrogen-fixing bacteria as compared with the weed species, early and medium maturing groundnut varieties used.

Based on the foregoing, the entire pegging process was apparently free from underground competition with the roots of weeds for moisture, space and available nutrients which eventually translated to better pod formation and grain filling.

5.5 Effects of Weed Control Methods on Growth of Groundnut

Based on the results obtained from the trials, the better groundnut growth in treatments with black polythene mulch and hoe weeding at 3 and 6 WAS because of the ability of these two weed control strategies in having a more efficient weed control when compared with others.

Likewise, the groundnut crop attained days to 50 percent flowering earlier in plot with black polythene mulch. The use of polythene tends to smother and kill all weeds as a result of high temperature generated as well as lack of light for photosynthesis by the weeds. This is not surprising because hoe weeding is known to remove all weeds, regardless of type, unlike most herbicide that are selective. Ibrahim (2015) reported that the highest values for vegetative growth recorded by two hoe-weeding was due to good weed control that allowed vigorous growth of the crop and development of larger vegetative parts with consequent high light interception for increased dry matter production. This result conforms with the findings of Mubarak (2004) who reported that efficient weed control enable plants to have easier access to more growth resources leading to early anthesis.

Creating a relatively weed-free condition as obtained under plastic mulch means reduced competition for growth factors such as light, moisture, nutrient and spaces between the crop and the weeds. Similarly, under these conditions, crops are less likely to suffer any injury from the use of chemical herbicides thereby giving it an edge to perform better than those exposed with to chemical weed control or those left un weeded. Yadava and Kaura (2007) reported that weed control in groundnut led to increased number of branches plant^{-1} as compared to groundnut plants whose plot was left un weeded. Also Hu *et al.* (1995) recorded earlier seedling emergence, improved crop growth and nodule development in groundnut as a result of the use of polythene mulch.

Hoe weeding at 3 and 6 WAS also contributed significantly to the accumulation of dry matter in groundnut which later transformed to yield, since the weed density has been managed efficiently, hence, there was apparently less competition for growth factors. On the other hand, the poor performance of the groundnut crop in un weeded plots could be due to severe competition for growth factors between weed species as well as between crop and weeds. This finding are in agreement with Adekpe (2005) who demonstrated that crops are known to perform better under good weed management.

5.6 Effect of Weed Control Methods on Yield of Groundnut

The significant variation in yield (pod and haulm) and yield components (shelling percentage and harvest index) of groundnut varieties when black polythene mulch or hoe weeding (3 and 6 WAS) was used could be due to effective utilization of trapped resources (moisture, heat, fertility) under black polythene mulch which in turn aided in reducing weed crop competition by smothering weeds from the onset of the seasons beyond the critical weed infestation period in groundnut which is about 6 WAS thereby allowing the crop to initiate pegging in the soil successfully without interference from the root system of weeds that are competing for space and other growth factors meant for the yield formation. Daisley *et al.* (1988) observed significant differences in weed control between mulched and un-mulched plots of egg plants and cowpea. In an experiment on the effect of black polythene film mulching on the growth and yield character of groundnut, Cheong *et al.* (1995) reported highly positive correlation of proportion of sound seeds, 100- seed weight and shelling ratio with seed yield of groundnut. Subrahmaniyan *et al*. (2012) reported a reduction in weed incidence and dry matter production with higher number of pods per plant, pod yield and shelling percentage with the use of polythene film mulch, compared to non- mulched plots. This is further confirmed by low crop performance in the weedy check with respect to growth and yield characters.

5.7 Effect of Time of Phosphorus Application on Weed Growth

The superiority recorded by time of phosphorus application at 2 weeks before sowing with respect to weed characters; like weed dry weight at 12 WAS and weed control efficiency could be due to the fact that phosphorus is an immobile element. Thus, weeds being opportunistic pests that utilize the availability of P and other growth factors in the soil to its advantage, leading to the rapid growth and development of the weed flora before the groundnut plants are established which the P was meant for, thereby reducing the quantity of the recommended rates of P that was allocated to the groundnut plants. According to Angonin *et al*. (1996) time of fertilizers application also influences weed species and their distribution patterns. Fertilizer should be applied at proper time so that weed infestation and proliferation can be checked in other to get maximum production from crop plants by optimized use of nutrients (Moody, 1977).

The presence of abundant weed seeds (seed bank) in the soil outnumbered the recommended sown groundnut seeds per hole, per stand and per hectare respectively. Naturally, weeds emerges faster, attained physiological maturity and then deposit there seeds in the soil for the next generation before even the groundnut plant attained full pegging stage. Evans *et al*. (2003) reported that time of fertilizer application can start or end the competition, while if fertilizer is applied at early crop growing season; weeds may be controlled to a substantial level.

5.8 Effect of Time of Phosphorus Application on Growth of Groundnut

At the termination of the trials, growth characters like crop growth rate and leaf area index, among others, were affected due to inconsistencies in the effect of time of phosphorus application.

As a result of good land preparation coupled with adequate moisture and ideal temperature for emergence of the groundnut plant, plots that received P at sowing utilized the nutrient for about two to three weeks after sowing which in turn translated to better growth depicted by fast plant crop growth before the emergence of the weeds in the field again, of which the plant has already well developed rooting system for absorption of more nutrient and thus withstanding competition of all forms with the newly emerged weeds.

Ayodele and Oso (2014) reported when P was applied at planting, it enhanced early vegetative growth in terms of plant height, number of leaves and leaf area per plant, while the control treatment gave the least values of these growth parameters which did not differ significantly from withholding P fertilizer application until 3 and 5 WAS.

5.9 Effect of Time of Phosphorus Application on Yield of Groundnut

The significant differences observed due to time of P application on yield characters of groundnut are attributed to drilling method of fertilizer application that was used. Thus loses of fertilizer to wind erosion or leaching was reduced. Therefore, a dense canopy was formed by the plant population due to presence of phosphorus application at sowing which helps in early root establishment and development, thereby binding the soil particles together which plays a major role in dry matter accumulation which may be responsible for large number of nodules in the root zone of the groundnut plant, thus initiate pod formation, and finally, pod-filling. This is in conformity with Michael *et al.* (2020) who reported that P fertilizer is required for plant growth and development as it helps in root development and also serves as energy source for the rhizobium which in turn may lead to increased nodule formation thereby enhancing N_2 fixation. The results obtained agree with the findings of Badar *et al.* (2015) who showed that the number of nodule per plant and root length increased when P was applied in combination with rhizobium inoculation. Also Ayodele and Oso (2014) reported that grain yield and yield components (number of pods.plant^{-1}, average pod length, number of seeds.pod^{-1}, 100-seed weight) were best and did not differ significantly with P applied at planting, 3 and 5 WAP , while the control treatment gave least values.

5.10 Factor Interactions

5.10.1 Variety and Weed Control Method

The combination of weedy check and SAMNUT-23 resulted in higher weed dry weight than that of other weed control methods and any of the varieties. This is a clear indication that the leaf size and the branching pattern in SAMNUT-23 could not prevent the spread of weeds as opposed to other varieties used.

The use of black polythene mulch or hoe weeding at 3 and 6 WAS on SAMNUT-24 controlled weeds effectively and produced the highest canopy spread at 12 WAS. This could be due to the fact that the variety was able to tolerate weed pressure and responded positively to the weed control methods used, coupled with the smothering effect provided by the canopy spread in addition to the ability of the variety to adapt well to the agro-ecology.

The interaction of variety and weed control method on nodule count at 30 DAS in 2019 at Samaru revealed that hoe weeding at 3 and 6 WAS with SAMNUT-22 or SAMNUT-24 and using black polythene mulch in SAMNUT-24 produced the highest nodule count at 30 DAS. These findings could be due to the higher stand count produced by the varieties than the others and also due to reduced weed populations in the field and presence of adequate nutrient in the soil, helps the plant to establish their rooting system early enough for effective nodulation without weed interference.

The interaction of variety and weed control method on leaf area index at 9 WAS in 2018 and 2019 at Samaru indicated that hoe weeding at 3 and 6 WAS in SAMNUT-22 in 2018 and the combination of black polythene mulch and SAMNUT-24 gave higher leaf area index at 9 WAS. This meant that both varieties which are semi-erect and produced larger leaves, therefore, gain more advantage in terms of covering more ground per square meter than SAMNUT-23 under good weed management.

On the other hand, the interaction of variety and weed control method on haulm yield over time at Samaru revealed that the combination of black polythene mulch and SAMNUT-24 gave more haulm yield than the remaining two-factor interaction. The reason for this superiority could be due to the genetic attribute of the variety since it was bred to attain haulm yield potential of about 2.5 – 3.0 t ha^{-1} with good agronomic practices in place and favourable weather conditions.

5.10.2 Variety and Time of Phosphorus Application

The interaction between variety and time of phosphorus application on weed control efficiency at Samaru in 2019 indicated that only time of phosphorus application at sowing with SAMNUT-24 recorded the lower weed control efficiency. All other combination between times of phosphorus application at 2 weeks before sowing and at sowing with all the varieties were the same and control weed effectively. This is probably because of the presence of moisture in the soil that helps dissolve the fertilizer (P) that was applied 2 WAS sowing, hence make it readily available for the particular variety to absorb. Thus gave it an edge over the other possible combinations.

Secondly, due to prior availability of nutrient and considering the facts that SAMNUT-24 was bred to attain physiological maturity within 85 – 90 days, thus enabling it to explore the available nutrient particularly (P) within a very short period thereby, expressing it's supremacy over SAMNUT-22 and SAMNUT-23.

5.11 Correlation Analysis

The significant and positive correlations recorded between pod yield and some weed, growth and yield characters (weed dry weight, weed control efficiency, canopy spread, leaf are index, CGR, shelling percentage and haulm yield) suggest an inter-dependence between these characters as important yield determinants. Roland (2016) reported strong and positive correlation between kernel yield and yield characters like number of pods plant^{-1}, pod weight plant^{-1}, number of kernel plant^{-1}, kernel weight plant^{-1}, 100-kernel weight, pod yield^{-1} and indicated that these characters are important yield indices. Also, Rilwanu (2019) reported that the positive and significant relationship between pod yield and most plant growth parameters indicate appreciable level of interdependence between the parameters.

5.12 Profitability Analysis

Based on the results obtained from the study, production of groundnut was profitable by using SAMNUT-24 with black polythene mulch and phosphorus application at sowing recorded the highest Net Farm Income (₦ 1,434,036). The Net Farm Income revealed the superiority of SAMNUT-24 over SAMNUT-22 and SAMNUT-23 respectively; black polythene mulch over the rest of the weed control practices used; and phosphorus application at sowing over phosphorus application at 2 weeks before sowing. The reason for the higher Net Farm Income of groundnut (SAMNUT-24) in this study could be as a result of effective use of resources as well as the use of improved groundnut varieties suitable to both agro ecologies, ideal weed management strategies with the application of phosphorus fertilizer at the most appropriate time.

Finally, this aforementioned package resulted in the maximum revenue generated and produced the best pod yield 2.50 t ha^{-1} at Samaru and 2.41 t ha^{-1} at Minjibir, while the haulm yield at Samaru and Minjibir was 2.78 t ha^{-1} and 2.36 t ha^{-1} respectively was recorded in the production of one hectare of groundnut.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The experiment was conducted in 2018 and 2019 wet seasons at the Teaching and Research Farms of Samaru College of Agriculture, Ahmadu Bello University Zaria, Kaduna State located in the northern Guinea savanna agro-ecological zone of Nigeria, and the Institute for Agricultural Research Station, Minjibir, Kano State in the Sudan savannah agro-ecological zone of Nigeria. The treatments consisted of three groundnut varieties (SAMNUT-22, SAMNUT-23, SAMNUT-24), five weed control methods (weedy check; black polythene mulch; pendimethalin at 1.5 kg a.i. ha^{-1} as pre- emergence herbicide followed by (fb) fluazifop-p-butyl at 1.0 kg a.i ha^{-1} applied at 3 WAS; intra-row spacing at 10 cm; hoe weeding at 3 and 6 WAS), and two times of phosphorus fertilizer application (2 weeks before sowing; at sowing). The treatments were laid out in a split plot design with a factorial combination of weed control method and time of phosphorus application in the main plot while groundnut variety was allocated to the sub-plot. Three replications were used.

The study revealed that SAMNUT-24 produced more stands, taller plants and wider canop, more nodules and had greater crop vigour. The same variety flowered earlier and had the lowest weed dry weight and weed cover score, while it produced the highest pod and haulm yields at harvest. However, SAMNUT-22 had significantly higher 100-kernel weight and kernel yield which is comparable to those of SAMNUT-24 across locations.

In terms of weed control methods, black polythene mulch had higher canopy spread, plant height, leaf area index and crop vigour than other weed control methods. Similarly, higher relative growth rate and nodule counts were recorded in groundnut grown with black polythene mulch and hoe weeding at 3 and 6 WAS when compared with other weed control methods. Weed dry weight, weed cover score, weed control efficiency and crop injury score were significantly low under black polythene mulch. In addition, pod yield, kernel yield, haulm yield, harvest index and shelling percentage were higher in groundnut grown with black polythene mulch.

The application of P at 2 weeks before sowing groundnut produced higher crop vigour score at 6 WAS at Samaru in both years and over time, crop growth rate at 6 WAS in both locations and relative growth rate at 6 WAS at Samaru and Minjibir in 2019 and over time at Samaru. However, applying P at sowing led to higher weed cover score at12 WAS at Samaru in 2018 and the year mean, 2019 at Minjibir and crop injury score at 6 WAS in Samaru.

The time of phosphorus application did not significantly affect groundnut stand count, plant height, days to 50 percent flowering, pod yield, kernel yield, haulm yield and shelling percentage.

Groundnut pod yield was positively and highly correlated with haulm yield. Pod yield and harvest index were positively correlated in both years and locations. However, the correlation was only significant in 2019 at Samaru ($r = 0.354^{*}$), while it was positive and highly significant at Minjibir in 2019 ($r = 0.462^{**}$).

The profitability analysis indicated that the growing of SAMNUT-24 with black polythene mulch and applying phosphorus at sowing gave the highest Net Farm Income.

6.2 Conclusions

From the study, the following conclusions can be drawn:

1. The use of SAMNUT-24 with black polythene mulch and P application 2 weeks before sowing or at sowing gave the highest yield of 2.50 t ha^{-1} at Samaru and 2.41 t ha^{-1} at Minjibir.
2. The use of SAMNUT-24 with black polythene mulch and P application at sowing gave the highest net farm income at Samaru (₦ 1,405,643) and Minjibir (₦ 1,434,036).

6.3 Recommendations

The following recommendations can be made from the study:

1. SAMNUT-24 for better pod and haulm yield at Samaru and Minjibir.
2. Black polythene mulch or hoe weeding at 3 and 6 WAS for boosting production of groundnut in Samaru and Minjibir, due to effective weed control.
3. P application at sowing for minimizing cost of production.

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Appendix I: Meteorological Data of the Experimental Site during 2018 and 2019 Wet Seasons at Samaru, Nigeria

	2018					2019				
		Temperature (°C)					Temperature (°C)			
Months	**Rainfall (mm)**	**Min**	**Max**	**Relative humidity (%)**	**Sunshine (MJ/M^2)**	**Rainfall (mm)**	**Min**	**Max**	**Relative humidity (%)**	**Sunshine (MJ/M^2)**
June	111.60	20.86	32.96	64.35	4.56	89.40	21.00	33.20	62.55	8.06
July	229.71	20.06	30.51	73.56	5.43	284.89	20.00	31.29	69.74	6.90
August	358.98	19.45	29.70	77.59	1.77	439.58	20.41	29.96	74.32	5.51
September	217.80	25.46	31.46	71.55	3.24	206.70	20.03	31.86	68.91	6.73
October	88.97	18.22	33.22	55.67	8.16	255.75	20.25	32.77	66.83	6.41
November	0.00	12.80	33.83	21.93	9.30	0.00	14.8	32.36	34.3	8.12

Source: Institute for Agricultural Research Meteorological Station (2018/2019).

Appendix II: Meteorological Data of the Experimental Site during 2018 and 2019 Wet Seasons at Minijibir, Nigeria.

	2018					2019				
		Temperature (^oC)					Temperature (^oC)			
Months	**Rainfall (mm)**	**Min**	**Max**	**Relative humidity (%)**	**Sunshine (MJ/M^2)**	**Rainfall (mm)**	**Min**	**Max**	**Relative humidity (%)**	**Sunshine (MJ/M^2)**
June	65.00	24.35	35.79	22.7	20.67	1.20	24.07	34.81	19.5	19.45
July	111.90	22.50	31.84	24.0	19.25	206.77	22.51	32.03	24.3	18.12
August	328.91	22.12	30.86	25.1	17.57	131.13	22.20	30.04	22.5	15.01
September	72.3	22.50	33.07	17.8	19.92	0.00	22.79	33.99	21.7	18.67
October	7.44	20.94	36.39	14.3	20.43	1.80	22.21	33.84	19.8	17.09
November	0.00	14.38	35.63	8.7	19.31	0.00	16.82	35.51	9.1	16.40

Source: Agricultural Research Station Minjibir, Meteorological Station (2018/2019).

Appendix III: Fixed and Variable Cost of Producing One Hectare of Groundnut.

Fixed cost

Cost	**₦ per Hectare**
Fixed cost	
Rent on land	6,000
Land clearing	5,000
Harrowing and ridging	10,000
Harvesting, picking, winnowing and storage	15,000
Fertilizer	9,000
Supervision	10,000
Charge on capital	8,000
Total Fixed cost	**63,000**

Appendix IV: Variable Cost of (₦) Producing One Hectare of Groundnut

Source: Market survey

Treatment	Cost of inputs	Cost of application/ planting	Total variable cost
Variety (V)			
SAMNUT-22	12000	5000	17000
SAMNUT-23	12000	5000	17000
SAMNUT-24	12000	5000	17000
Weed control methods (W)			
Weedy check	0	0	0
Black polythene mulch	40000	8000	48000
Pendimethalin at 1.5 kg a.i. ha^{-1} fb. fluazifop-p-butyl at 1.0 kg a.i. ha^{-1} at 3 WAS	10800	4000	14800
Hoe weeding at 3 and 6 WAS	15000	0	15000
10 cm intra-row spacing	6000	0	6000
Time of phosphorus application (P)			
2 weeks before sowing	9000	2600	11600
At sowing	9000	2600	11600

Appendix V: Weed Cover Score

Effect	Rating	Weed Cover Description
Low	1	No weed cover
	2	Satisfactory to good weed control
	3	Weed control some worthless than satisfactory
Medium	4	Moderate weed control
	5	Satisfactory weed control
	6	Deficient weed control
High	7	Poor weed control
	8	Very poor weed control
	9	Complete weed cover

Appendix VI: Crop Vigour Score

Effect	Rating	Crop Vigour Description
Low	1	Completely dead plants
	2	Moribund (few green leaves observed)
	3	Only few green tissues present
Medium	4	Definite growth reduction, severe toxicity symptoms and less likely to survive
	5	Distinguishable inhibition of growth and other injury symptoms
	6	Distinguishable inhibition and slightly discolouration and necrotic spots
High	7	Distinguishable inhibition of growth
	8	Slight distinguishable and lower vigour/ discolouration and necrotic spots.
	9	Fully established plant

Appendix VII: Crop Injury Score

Effect	Rating	Crop Injury Description
Low	1	Least injured plant
	2	Low crop discolouration or stunting
	3	Moderate crop discolouration or stunting with stand loss
Medium	4	High crop discolouration or stunting with more stand loss
	5	Crop injury pronounced
	6	Crop injury more pronounced, with lasting effect
High	7	Moderate crop destruction
	8	Severe crop destruction
	9	Complete crop destruction

BIOGRAPHY

Name	JIBRIN Dahiru Mohammed
Date of Birth and Place of Birth	17th March, 1981. Kano
Marital Status	Married
State of Origin	Bauchi State
Local Government Area	Katagum

Educational Qualification

M.sc. Agronomy	Bayero University Kano	2013 - 2015
PGD Crop Production Management	Department of Agronomy, ABU, Zaria.	2012 - 2013
HND Pest Management Technology	Samaru College of Agriculture	2007 - 2009
ND Agricultural Technology	Samaru College of Agriculture	2002 - 2005
Certificate in ICT for Rural Development in India.	National Institute of Rural Development, Hydrabad, India.	2014
Certificate in Working at a Small to-Medium Business or ISP/ Networking for home and small businesses.	CISCO Networking Academy, ABU Zaria	2011
Diploma in Computer	(Data Processing and Information) Sham-Lad Professional Computer Institute, Kano	1998
Secondary School Attended	F. O Ahmadiyya Sec. Sch., Kano	1992 - 1998
Primary School Attended	Custom Staff School, Kano	1986 - 1992

Working Experience

Youth Corp Member	National Assembly, Abuja	2010 - 2011
Data Entry Clerk	Project Swift Count, Abuja	2011
Computer Engineer	Sprotech Venture, Zaria	2005 - 2008

Present Employment

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