EFFECT OF WEED CONTROL METHOD AND PERIOD OF WEED INTERFERENCE ON GROWTH AND YIELD OF ROSELLE (*Hibiscus sabdariffa* L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) IN AGRONOMY

DEPARTMENT OF AGRONOMY,

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AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA

FEBRUARY, 2021

DECLARATION

I hereby declare that the work in this thesis entitled “EFFECT OF WEED CONTROL METHOD AND PERIOD OF WEED INTERFERENCE ON GROWTH AND YIELD OF ROSELLE (*Hisbiscus sabdariffa* L.) IN NORTHERN GUINEA SAVANNA OF NIGERIA” has been carried out by me in the Department of Agronomy, under the supervision of Professors .L. Aliyu, N.C. Kuchinda and D.I Adekpe. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Thesis was previously presented for another Degree or Diploma at this or any other institution.

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Ramat MOHAMMED Signature Date

The above declaration is confirmed

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Professor. L. Aliyu Date

CERTIFICATION

This Thesis “EFFECT OF WEED CONTROL METHOD AND PERIOD OF WEED INTERFERENCE ON GROWTH AND YIELD OF ROSELLE (*Hibiscus sabdariffa* L.) IN THE NORTHERN GUINEA SAVANNA OF NIGERIA by Ramat MOHAMMED meets the regulation governing the award of Doctor of Philosophy in Agronomy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to God Almighty and my parents to whom I owe everything since I was born, to my husband, who supported and encouraged me at all stages of my study, and to my beloved sons Abdulkadir and Muhammad and beloved daughters Aisha and Fatima, who have been a great source of encouragement.

ACKNOWLEDGEMENTS

I praise Allah for the blessings and guidance received in carrying out this work to great success. This work would not have been possible if not by the power of Almighty Allah and the assistance and encouragement of a number of people who did not only give me stimulated impetus, but also offered their support.

My unalloyed gratitude goes to the Chairman of my Supervisory Committee, Prof. L Aliyu, for all his patience, help, and high level of encouragement, constructive criticisms and tireless guidance during the course of this work. I am also grateful to the other members of the committee namely Prof. N. C. Kuchinda and Prof. D. I. Adekpe that made the movement of the cart possible. I sincerely appreciate their support, guidance and direction as well as invaluable advice throughout the research work and write-up.

My sincere appreciation goes to the Head of the Department of Agronomy Professor A.I. Sherifai for his support. My special thanks to Professors O. O. Olufajo, V. Ogunlela, U. F.Chiezey, E.B.Amans, I. U Abubakar, A.B Lawal, J.A.Y Shebayan, E.C. Odion, D.Ishaya, B. A. Babaji, H. Mani and A.A Mukhtar, and M.A Mahadi, as well as to other academic and non-academic staff of Department of Agronomy for their moral support and academic advice. At this juncture, I would like to remember my late Supervisor; Prof. B. Tanimu of blessed memory, fondly remembered for his unflinching moral support and encouragement. May God grant his soul Al-jannah Firdaus, Aamiin. My sincere appreciation also goes to my senior colleagues. Drs.R.A. Yahaya, N. Kura, U.L.Arunah, A.S.Isah and Usman Ibrahim for their unflinching support and rare kind gestures.

I am particularly indebted to the Executive Director of Forestry Research Institute of Nigeria, Professor O.A. Adepoju, the Provost, Federal College of Forestry Mechanization, Afaka, Kaduna, Dr .M. B. Usman, members of staff of Crop Production Technology, department Dr .U. U. Emeghara, Dr. M. M Olorukooba and other colleagues in the College for their immense support towards the completion of this work.

I owe gratitude to the relentless, financial, moral support, love and care shown to me by my beloved husband Dr. Abdullahi Shehu and children Aisha, Abdulkadir, Fatima, Muhammad and Dr Musbaudeen Muhammed Raji and others in my custody for their understanding, inspiration, affection and perseverance during this program.

To my parents (Late Alhaji Mohammed Mahmud Buhari and Alhaja Raliat Mohammed Mahmud Buhari) fondly remembered whose foresight and sacrifice laid a solid foundation for my educational pursuit, may God grant their souls Al-jannah Firdaus, Aamiin. Also, to my brothers, brother in-laws and friends, who inspired and motivated me to forge ahead. I say thank you may God reward you in multiple folds, Aamiin. For all others that have imparted positively on me at different levels and at various times during my educational pursuit and career, I profoundly appreciate their immense contributions. For want of space, I am unable to mention your names individually but I ask God, Almighty to reward you abundantly, Aamiin.

Finally, I also wish to thank the Institute for Agricultural Research, Samaru, Zaria and Forestry Research Institute of Nigeria, Afaka, Kaduna, for giving me the opportunity to conduct these trials on their experimental farms and for granting me the permission to do this course.

ABSTRACT

Two field trials were conducted during the wet seasons of 2011 and 2012 at the experimental Farms of the Institute for Agricultural Research, Samaru (Lat. 11^0 11^1, Long. 07^0, 38^1; 686m above sea level) and Federal College of Forestry Mechanization, Afaka, (Lat 10^0, 03^1, Long. 07^0, 21^1; 644m above sea level), both in the northern Guinea savanna of Nigeria. The aim was to evaluate the influence of weed control method and period of weed interference on growth and yield of roselle (*Hibiscus sabdariffa* L.). Experiment I consisted of fourteen treatments (oxadiazon at 1.5 and 2.0 kg a.i. /ha, diuron at 2.0 and 2.5 kg a.i /ha, metolachlor at 1.5 and 2.0 kg a.i /ha, butachlor at 1.5 and 2.0 kg a.i /ha and pendimethalin at 1.5 and 2.0 kg a.i /ha, hoe weeding at 4; 3 and 6 and 3, 6 and 9 weeks after sowing (WAS) and a weedy check). Experiment II consisted of ten periods of weed interference in two sets of treatments: In the first set, plots were initially kept weed free by hoe- weeding for 3, 6, 9 and 12 weeks after sowing (WAS) and left weed infested thereafter. In the second, plots were left weed infested initially for the corresponding periods and kept weed free thereafter. There were two controls: plots kept weed free throughout the crop life cycle and plots left weed infested throughout the crop life-cycle.Each experiment was laid out in a Randomized Complete Block Design (RCBD), replicated three times. In Experiment I, the herbicide treatments could not effectively control the weeds beyond 6WAS, except diuron at 2.0 and 2.5kg a.i /ha and oxadiazon at 1.5 and 2.0 kg a.i /ha. Application of diuron at 2.5 kg a.i /ha gave significantly lower weed cover, weed dry matter and highest weed control index than the other herbicide treatments and were comparable to two hoe-weeding at 3 and 6WAS at all sampling periods. Highest crop injury was obtained by the application of diuron at 2.5

kg a.i /ha in 2011 at both locations. Among the herbicides, pendimethalin, metolachlor and butachlor each at 1.5 and 2.0 kg a.i /ha were consistent in combining good weed control with higher crop growth and yield. Pendimethalin at 2.0 kg a.i /ha gave significantly higher herbicide efficiency index in both years of trials at the two locations, more number of leaves, taller plant and thicker stem and more number of primary, secondary and tertiary branches, compared to other herbicide treatments. As a result of these, more number of calyx/plant, higher calyx yield/plant and calyx yield, more number of seeds/capsule, heavier seeds/capsule and greater 100 seed weight were also obtained. The treatment also gave higher combined yield at both locations, except in 2012 at Afaka, where metolachlor at 1.5 kg a.i /ha gave higher yield. In experiment II at both locations in the two years of studies, uncontrolled weed growth throughout the crop life-cycle significantly depressed the growth and yield of roselle. Keeping the plots weed free initially for 3WAS only did not prevent suppression in crop growth and yield of roselle; while initial weed infestation for the first 3WAS had no adverse effect on the crop. Keeping the plots weed infested for 6WAS and longer depressed various crop growth characters and calyx yield compared with the crop kept weed free for 6WAS and longer. The crop was most critically affected by weed between 4 and 6 WAS. Plots left initially weed infested for 3WAS produced calyx yield comparable to those kept weed free for 6WAS and longer. Number of seeds/capsule, weight of seed/capsule and 100 seed weight were not significantly affected by any of the factors evaluated in the two experiments in the two years of studies. Simple correlation matrix among some growth and yield characters of roselle in the two experiments revealed that plant height, number of leaves, stem girth and number of primary and secondary branches at 9 WAS and number and

calyx weight/plant were positively and strongly correlated with the calyx yield. The weedy check significantly reduced calyx yield by 72.68%, 24.54% and 59.27%, 45.98% at Samaru and Afaka, in 2011 and 2012, respectively. The combined yield losses at both locations were 47.17% and 51.76% in weed control experiment. In the weed interference experiment, the yield losses were 60.76%, 59.40% and 61.11%, 48.12% in 2011 and 2012 and combined yield losses were 60.01% and 54.62 at Samaru and Afaka, respectively. The cost benefit analysis for weed control at Samaru in 2011 and 2012 showed that pendimethalin at 1.5 kg a.i /ha gave the best economic returns of ₦100,000.00 and ₦114,000.00 while at Afaka, pendimethalin and metolachlor both at 1. 5 kg a.i /ha gave ₦ 24,800.00 and ₦53,750 ,00 in 2011 and 2012. Hoe- weeding at 3, 6, 9 WAS gave ₦96,450.00, ₦116,150.00 and ₦27,250.00, ₦53,350,00 in 2011, 2012 at Samaru and Afaka, respectively. In experiment II, plots kept weed free for 6WAS gave best economic returns of ₦123,800.00 and ₦141,500.00 in 2011 and 2012, respectively at Samaru and plots kept weed free for 6WAS and 9WAS gave best economic returns of – ₦41,100.00 and ₦96,300.00 at Afaka in 2011 and 2012, respectively when compared with plots kept weed free throughout the crop life-cycle of ₦108,400.00, ₦125,000.00 at Samaru and – ₦54,100.00, ₦85,300.00 at Afaka in both years of study. The nutritional quality of calyx analyzed in Experiment I included Protein, Fibre, Ash, Iron, Calcium, Ascorbic acid and Vitamins B1, B2, D and B complex, and treatment had the similar values. In conclusion, for effective weed control and higher calyx yield, pendimethalin at 1.5 kg a.i /ha or metolachlor at 1.5 kg a.i /ha can be adopted by roselle farmers and should keep their farm weed free for 6WAS, since the critical period for weed competition of roselle was found to be between 4 and 6WAS at these locations.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Origin, Production Trend and Uses

Roselle (*Hibiscus sabdariffa* L.) is one of the underexploited food crops with nutritional and food industry processing potential (Leung and Foster, 1996). It is a fibre crop of the family *Malvaceae*. It is known in different countries by various common names which include: rosella fruit in Australia, rosella in Indonesia, sorrel in Jamaica Central America, Karkade in Egypt and Saudi Arabia, and Zoborodo in Nigeria (Abu-Tarboush and Ahmed, 1996; Ross 2003; Ali *et al*., 2005; Mahadlevan *et al*., 2009; Kays, 2011; Wang *et al*., 2012). It is probably native to West Africa although known in the West Indies early in the 16^{th} century and was grown in Asia by the 17^{th} century ((Grubben, 1994; Schippers, 2000; EBI, 2017). In this century, vegetable types were introduced to India and Americas. Roselle is commonly propagated in different parts of the world including USA, United Kingdom, India, Saudi Arabia, China, Malaysia and Indonesia (Rao, 1996; Chewonarin *et al*., 1999; Dung *et al*., 1999; Babajide *et al.*, 2004; Yaqoub *et al*., 2004; Fasoyiro and Owosibo 2005; Ismail *et al*., 2008; Eslaminejad and Zakaria, 2011). Benin,Sudan, Cote D' ivore, Ghana, Niger, Burkina faso and Nigeria were reported as major producing countries of roselle in Africa (Babatunde and Mofoke, 2006 ; Oyewole and Mera, 2010). India and the Philippine are the world major producers (EBI, 2017). Sudan is the major country in tropical Africa producing dried roselle calyces for local consumption, and export is mainly from the Kordorfan and Darfur regions in the country. International trade in roselle calyces has increased steadily over the last decade, about 15,000 metric tones per year now entering the world market FAO (2007). Germany and the United States are largest importers and paid 1200 -1700US $/t Egyptian for Sudanese roselle.

In Nigeria, roselle is widely cultivated in the forest and savanna zones, where it has industrial potential and medicinal, commercial and domestic uses (Schippers, 2000; Alegbejo *et al.*, 2003). It is a multi-product and multi-purpose plant: the leaves, edible calyces, seed and fiber are utilized in a variety of ways in the home and the industry. It is popularly referred to as "zobo" in Western Nigeria and "zoborodo" in Northern Nigeria.

There are two main types of roselle: The first being *H.sabdariffa var altissima Wester*, which is more important economically and is cultivated for its jute-like fibre in India, the East-Indies, Nigeria and South America. The second *H.sabdariffa var sabdariffa* includes shorter bushy forms, which have been described as races: *bhagal-puriensi*, *intermedius*, *albus* and *ruber*. The first type has green, red-streaked, inedible calyces, while the second and third types of races have yellow-green and is also widely exploited for its edible calyces race. *ruber* (Morton, 1987; Abu-Tarboush *et al*., 1997). *Hibiscus sabdariffa*. *var*. *sabdariffa* race *ruber* is an erect and branched annual or biennial herbaceous sub-shrub of 0.5-3m tall with a strong tap-root system and a smooth or nearly smooth, cylindrical typically green or red stem depending on the seed source. The leaves are alternate 7.5-12.5cm, long green with reddish veins and long or short petioles (Eslaminejad *et al*., 2012). The flowers are broad on very short peduncles in the axils of the upper leaves with the diameter of 8-10 cm and are dark green to red. Alternate hairless, long petiole palmate divided with 3-7 lobes with serrated margins, flower solitary in leaf axils, bisexual, regular, pedicel up to 2cm long. The calyces are large, fleshy with 8-10 segment united at base, pale yellow or pale pink with dark red-purple center, the fruits are egg-shaped, up to 2.5cm long enclosed by calyces and many seeded (Chau *et al*., 2014).The seeds are kidney-shaped up to 0.7m long, dark brown epigeal germination, the epicalyces are made up of ten (10) linear fleshy bracteoles and the calyces are eight (8) lobed becoming large and fleshy after flowering (Gibbon and Pain,1985; Morton 1987).The seed pod (capsule) begin ripens near the bottom and proceed to the top.

Roselle is cultivated in tropical and sub- tropical regions. It is a short-day plant with a critical photo-period of 12-12.5 hours (Robert, 2005) and thrives best in hot areas with high humidity and temperatures of about 18^0-35^0 C (Amusa, 2004). It has been shown that the plant requires optimum $_{p}$H of 5.5-7.5 and rainfall of 1000 – 1600mm, with minimum of 100– 500mm/month during its vegetative growth. The rainfall should be well distributed over 90 -120 days during the growing season (Plotto and Anne, 2004). Roselle prefers soil of deep, fertile, well drained loam, and has tolerance to drought, but sensitive to flood (Duke, 1983). A single plant produces about 1.5kg of fruit, approximately 8t/ha. Yields of leaves may be about 10t/ha (EcoCrop, 2007). Roselle is grown for its stem, fibre, edible calyx, leaves and seeds.

It is one of the most useful medicinal plant which has several properties such as; antiseptic, aphrodiasic, chlolagogue, digestive agent and a diuretic (Akindahunsi and Olaleye, 2003; Aziz *et al*., 2007) and as a folk medicine for cancer, obesity, diabetes and hypertension (Tabut *et al*., 2003). It has many applications among folks in many countries of the world: In China, it is used for the treatment of hypertension, pyrexia, cholesterol level in blood and liver damage (Obiefuna *et al*., 1994; Adegunloye *et al*., 1996; Faraji and Tarkhan, 1999; Onyenekwe *et al*., 1999). Recent studies demonstrated that calyx presents antimicrobial as well as antioxidant activities due to its phenolic compounds (Fasoyiro and Owosibo, 2005). Its extract obtained from calyx is effective in the treatment of leukemia (Ibrahim and Hussien, 2006). It can also be used in the treatment of viral hepatitis (Dupriez and de

Leener, 1989) cardiac nerve diseases and cancer (Anon, 2007) and in the build-up of body immune system against diseases (CTA, 2001).

The calyx which is the most valuable part of roselle plant is used for the preparation of local and commercial soft-drinks in Nigeria, popularly called zoborodo or zobo and while roselle apple drink has contributed to the rapid increases in interest and demand for the crop (Fasoyiro and Owosibo, 2005). In West Indies the fresh calyx is used for making wine, jellies, syrup, gelatin beverages, pudding and cakes, and dried ones are used for tea, jellies, mermaid, ice-cream, sherbets, butter, pies, tans and other deserts (Aoshima *et al.*, 2007). A strong fibre obtained from the stem is used for various household purposes, including making of sack cloth, twine and cord (Bolade *et al.*, 2009). For non-food applications, the flower and fleshy fruits are used in pharmaceutical industry to relieve symptoms of bronchitis and cough. Calyces from the roselle flower, are very high in vitamin C, and are processed to produce juice. Duke and Atchley (1984) reported 100g of fresh calyx contains 85.59% moisture, 2.85 /ug vitamin D, 0.04mg vitamin B1, 0.6mg vitamin B_2 and 0.5mg vitamin B complex, 49 calories, 1-9g protein, 0.1g fat, 12.3g total carbohydrate, 2.3g fiber, 1.2g ash, 1.72mg calcium, 57mg Iron, 300ug Beta carotene equivalent and 14mg ascorbic acid/100g. In contrast, the dried calyx contains high amount of ascorbic acid between 280 -360mg/100g.This indicates that roselle has a higher content of ascorbic acid than guava and orange (Tee *et a*l., 1997).The calyx is high in anthocyanin, a good odorant and also a potentially good source of antioxidant components.

The fresh leaves are used as vegetables and potherbs (Grubben 1994; Schippers 2000), the young shoots at tender stage (6 - 8 weeks) are eaten either raw in salads or as cooked green alone or in combination with other vegetables, meat or fish (Plotto, 2007; Ismail *et al.*, 2008). The leaf of the roselle plant contains 43 calories, 85.6% moisture, 3.3g protein, 3.3g fat, 9.2g total carbohydrate, 1.6g fiber, 1.6g ash, 214mg P, 4.8mg Fe, 41.35k/g P carotene equivalent, 0.17mg Thiamine, 0.45mg riboflavin, 0.5mg niacin and 54mg ascorbic acid (Duke and Atchley, 1984).

The roselle seed with (17 – 20%) oil is also a good source of edible protein (23%) and has high lycin and tryptophan contents. Roselle seed contains 6-8% moisture, 18 –22% crude protein, 19 – 22% fat, 5.4% ash, 39 – 42% total dietary fiber, 119 – 128mg Ca, 596 – 672mg P, 4.0mg Zn, 3.1mg Cu, 393 – 396mg , 0.08 – 0.18Cr, 0.36 – 0.51mg riboflavin and 0.9mg nicotinic acid (Rao, 1996). The seeds have been explored to substitute coffee for human consumption and are considered an excellent feed for chicken (Morton, 1987; Maikano Mohammed Ari *et al*., 2014). In Africa, roselle seeds are roasted and ground into powder and used in oily soap and sauces as meal for human consumption (Atta and Imazumi, 2002). The seed is said to have aphrodisiac properties (Duke, 1983). In Northern Nigeria, the seeds are fermented into a condiment known as *Mungza ntusa* (Omobuwajo *et al*., 2000). Besides, roselle seeds are used for medicinal purposes in some countries. In Myanmar, the seeds are used to treat debility (Perry, 1980).

1.2 Justification for the Study.

Roselle is a promising crop due to its numerous medicinal and industrial uses. In Nigeria, roselle cultivation has gained wide acceptance among the farmers due to its medicinal applications (Olaniran *et al*., 2013) and food industry processing potential (Leung and Foster 1996; Egharevba and Law-Ogbomo, 2007; Aoshima *et al.*, 2007) and its potential as a high value export commodity, particularly now that the calyx yield is considered as much as the ribbon.The drink made from the calyx which is receiving industrial attention internationally (Egharevba and Law-Ogbomo, 2007) is readily available and inexpensive source of vitamin C (Babajide *et al*., 2004). According to Cisse *et al.* (2009) roselle plays an important role in providing nutritional health security and income generation among rural farmers in developing countries.The authors further stated that there is a need for increase in roselle production in order to meet the current demand. There is paucity of information on the extent of yield reduction caused by weed interference and weed control method in roselle particularly in Nigeria and other growing areas despite the beneficial uses of this crop and its cosmopolitan nature, there is dearth of information about the crop. This could be due to the fact that it is still limited to small-holding under subsistence practice and grown predominantly in mixtures with other crops such as cereals and tree crop and also sometimes on the border edge of field devoted to other crops. Most farmers cultivate roselle mainly for local consumption; therefore, its production has remained at a subsistence level. Roselle, though has been cultivated for centuries in Africa, its production has not received much research attention probably due to preference for related crops such as kenaf, jute and vegetable crops that serve as local substitute for fibre or vegetable. The increasing public awareness on roselle based on its medicinal and industrial value which is already assuming greater prominence (Babajide *et al.*,2004), coupled with increasing human population especially in Nigeria, there is a need for extensive research to explore the potential of this crop in large commercial production.

Many factors affect the growth and yield of crops, roselle, like other crop also inclusive and these include: inappropriate planting methods, the use of low yielding cultivars, inadequate precipitation and soil alkalinity, in efficient weed control method and pests and disease management practices (Kebbeh *et al*., 2003). Weeds are one of the most important factors that influence agricultural production system (Oad *et a*l., 2007; Aghaali Kani and Yaghoobi, 2008; Karamati *et al*., 2008 and Yaghoob and Siyami, 2008).Weed is as old as agriculture, and from the very beginning farmers realized that the weeds interfer with crop production (Ghersa *et al*., 2000). Weeds compete with crop plant for light, moisture, space and nutrients and consequently interfere with normal growth and yield (Mubeen *et al*., 2009). Weed interference not only results in crop losses but also increases insect pest damage, harvesting difficulties and crop contamination (Ohene, 1998). According to Bibi *et al*. (2005) among the factors affecting crop yield, the most serious but less noticeable causes of low yield is weed infestation. It is generally conceded that the recurrent economic damage to agriculture by weeds far surpasses the more incidental damage inflicted by insect pests, rodents and diseases.Adigun (2009) reported 50-60% reduction in potential roselle fruit yield in response to unchecked weed infestation. Ahmed *et al.* (2012) also reported 75% yield losses in roselle as a result of unchecked weed. Roselle, like most plant is known to be susceptible to weed competition. Weeds exert stress on the cultivated crop through their interference with the crop allelopathic and parasitic effect and the crops needs to be kept free from weeds at critical stages to prevent crop yield loss (Knezevic *et al*., 2002). Inevitably allowing weeds to grow uncontrolled will later lead to reduction in crop yield (Takim and Fadayomi, 2013).The infestation by weeds is considered to be one of the major problem among biotic stresses (Dil-Baugh *et al*., 2009). It was reported that the main poor crop management practice was an inefficient weed control program (Sultan, 2004).Weed control is most difficult when the crop plant seedlings are very young and is more beneficial before the commencement of reproductive phase (Dil Baugh *et al*., 2014). Weed control are mainly done with herbicides by some farmers, which is associated with risk of environmental hazards and development of herbicide resistance on weed (Abdulhakim *et al.*, 2013). In a sustainable weed management strategies control of weeds at the proper time should be adopted in order to avoid environmental hazards as well as economic loss. Some general assumption about weed-crop interference can help make the appropriate management decision. Attention must therefore be focused on period of weed interference and control measure in roselle so as to maintain the competitive ability of the threatened plant by minimizing weed interference during the growth phases of the crop. The period of weed interference influences strongly on the choice of weed control measures. Information is therefore needed on the critical periodof weed interference this would enable farmer to achieve early crop establishment, good vegetative growth and higher yield of the crop.

A weed control method, effective in one set of conditions may not be effective in other set (Nadeem *et al.*, 2013). Among the smallholder farmers in Africa, the traditional methods of weed control, namely, hoe-weeding, is the commonly used method by the resource poor farmers and consumes over 40% of total farm budget (Babalola, 2002). This method is not only labour intensive, expensive and strenuous, but can also cause mechanical damage to branches and roots of plants as well as drudgery to humans (Olunuga and Akobundu, 1980). In addition to high cost, labour availability is uncertain, thus making timeliness of weeding difficult to be achieved, especially during the peak period of weeding thereby resulting in yield loss (Adigun, 2003; Adesina *et al.*, 2009). It is in light of the enumerated constraints to cultural weed control method that the use of herbicide is considered more promising.

Chemical weed control is an alternative to manual weeding because it is cheaper, faster more adapted to large scale crop production than other weed control options, and gives better weed control (Anon, 1994; Chikoye *et al.*, 2005; Chikoye *et al.*,2007). Chemical control of weeds when correctly employed not only reduces labour requirement but controls weed from planting to harvest and promotes higher yields. Regardless of the nature of weeds, herbicide use minimizes soil erosion and displacement of plant nutrients since it does not disturb the soil. It reduces the drudgery of hand-weeding and time spent on the operation could be devoted to other farming operations and social activities such as schooling, trading etc (Akobundu 1987; Lagoke *et al*., 1988). Herbicide use has been reported to be more profitable than hoe-weeding in the production of various crops in Nigeria (Ogungbile and Lagoke, 1986; Adigun *et al*., 1993).To achieve high roselle yield the combined application of period of weed interference and weed control are essential. Knowledge of the relationship between the periods of weed interference coupled with the critical period (special time) can help farmers to manipulate weed control measure to favor the plant and suppress weed growth. Presently, there is dearth of information on yield losses on weeds interference period and the use of herbicides in roselle.

Many herbicides have been reported for weed control in roselle, and these include galex (metolachlor + prometryn) and oxadiazon (Adigun, 2009). Other herbicides include codal (metolachlor + metobromuron), oxadiazon (Ronstar) and pendimethalin (stomp) (Adekpe and Adigun, 2000). The identification of new and potent herbicides that will reduce the problem of weeds in roselle will be a great breakthrough in increasing roselle production in Nigeria. It is in view of these, that this study was undertaken.

1.3 Objective of the Study

The study was conducted to achieve the following objectives:

i. To evaluate the effect of various weed control methods for effective weed control in roselle.
ii. To determine the critical period of weed interference in roselle
iii. To evaluate the cost-benefit ratio of the various weed control options.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Losses due to Weed Competition in Roselle

Many factors affect the yield of crops, but one of the most serious but less noticeable causes of low yields is weed infestation (Bibi *et al.,* 2005). Weeds have been defined as higher plants in the Agro-ecosystem which are not sown, undesired, out of place or generally as plants which do more harm than good (El-Naim and Ahmed, 2010).Smith (2009) defines weeds as plant growing in places (spatial occurrence) and at times (temporal occurrence) where other plants are desired (cropping situation) or where no plant is desired at all (non-cropping situation). All weeds are unwanted plants but not all unwanted plants are weeds. Weeds are serious menace responsible for blocking the way of improving yields of crops (Muhammed *et al*., 2013). Weed is number one pest which farmers contend with in most crops in Nigeria. Ayeni (1991) ranked weeds as number one pest which farmers are well familiar with causing crop losses, as more energy is spent on weeding than any other single human cropping task.Weed is an important constraint in agricultural production system, acting at the same level as the crop, weed capture a part of the available resources that are essential for plant growth. Inevitably, allowing weed uncontrolled will later lead to reduction or total loss in crop yield (Takim and Fadayomi, 2013). Agboola (1994) reported that, in some cases weed resulted in the abandonment of crop field. Weeds remove plant nutrients more efficiently than crop plant. Jain *et al*. (1981) reported that, weeds consume 5-6 times nitrogen, 5-12 times phosphorous and 2-5 times potassium more than cotton crop at the early growth stages and thus reduces cotton seed yield from 54 to 85%. In a drought situation, they thrive better than crop plants when left undisturbed. They can curtail sunlight and adversely affect photosynthesis and crop productivity (Rao, 2004). Depending on the degree of competition, weeds reduce crop yield by 10 to 25% (Rao, 2004).

Rain (1991) and Mennanet *et al*.(2009) gave estimate of yield losses to weed in Nigeria to range from 40-100%. Weeds are the most deleterious pests that cause 69-92% reduction in crops yields (Lagoke *et al*., 1981; Magani 1990). The crop suffers losses due to presence of weeds, and weeds not only compete with the crop for nutrients, moisture, light, heat energy and space, but also harbor insects' pests and diseases (Anderson, 1982; Bukun, 2004; Iftikhar *et al*., 2010). Parker and Fryer (1975) estimated that the world is losing 11.5% of total food production annually as a result of weed infestation, and that the current world food production would be higher by 11.5% or 450 million tonnes if there was no weed infestation (Rao, 2004).

The cumulative effects of weeds on crops include strong competition for sunlight, nutrients, water and space (Akobundu, 1987). Concise information on losses due to weeds on roselle is limiting, particularly in the northern Guinea savanna of Nigeria. Weeds have different competitive abilities, which determine their performance and potential of damage in a given situation; and most importantly have vigorous growth habit, seed production, regenerative capacities and time of germination.Weed infestation leads to direct yield losses through competition with the crop for water, nutrients, light, space and / or carbondioxide (Akobundu, 1987). This degree of damage is mainly a function of their number, type biomass and leaf area index as compared with that of the crop. Competition for light has been identified as primary cause of crop yield loss in many crop- weed competitions (Munger *et al*., 1987; Kropff *et al*., 1987;Linquist and Mortenssen, 1999).Yield loss due to weeds is estimated to be 38% in Africa, 10 – 95% in Nigeria and 64-75% in northern Guinea savanna (Lagoke *et al*., 1981a; Anon, 1994 and Michael *et al*., 2009).Crop competition with weeds reduces crop yield more than attacks by insect pest or fungi because they are not always present, but crops always have weeds (Michael *et al*., 2009). Generally, an increase in one kilogram of weed drymatter corresponds to a reduction in one kilogram of crop drymatter (Rao, 2004).

Weeds may impair crop growth and quality. Noxious weed seeds greatly reduce the value of crop seed and grain and sometimes even render them unmarketable. The presence of weed debris in grains and other farm products reduces their market value and causes spoilage during storage (Rao, 2004). Ibrahim *et al*. (1999) reported a decrease of 42.0-49.6% in cotton yield due to presence of weeds throughout the growth period. Lagoke *et al*. (1981a) reported a fibre yield loss of up to 59% due to unchecked weed growth in kenaf. Kuchinda *et al*. (1991) reported that weeds resulted in the reduction of 47.2% and 30% fibre and seed yields, respectively, when compared with the best weed control treatment in a trial.Yield loss as a result of uncontrolled weed in okra field was reported to range between 88-99% in Nigeria (Adejonwo *et al*., 1989; Olabode, 2004). Adeyemi *et al*. (2015) reported a yield reduction of 89.31% and 87.28% in early and late season okra, respectively.

2.2 Effect of Weed Interference Period on Roselle.

Interference period indicate the time at which control is not necessary because of the absence of negative interaction between weeds and crops, and the appropriate time to perform weed control in crops (PSCAS, 2017).The menace constituted by weed interference is a major problem facing farmers in the tropics where the yield losses in non-weeded plot are estimated to range from 20-60%. Crop-weed interference encompasses the early physiological responses of the crop that are triggered by the presence of nearby weeds.It is well established that plants can perceive the presence of a neighboring competing for a resource that will become limiting later on the growing. Weed interference reduces crop yield by influencing the pattern of crop growth for limiting resources such as light, water or nutrients. Many factors influence weed interference and these include weed interference time and duration; weed density, nutrients level and environmental condition (Zimdahl, 2004). Although herbicides are widely used to manage weed populations, some weed inevitably escape control and survive to produce seeds. These seeds are often retained in a soil seed bank that can survive over years or even decades. It is this persistence that ensures thatefficacious weed management will remain a pressing issue for farmers for many years to come.

The relative time of crop and weed emergence is perhaps the most important factor influencing the outcome of crop weed competition (Blackshaw and Harker, 1998; Knezevic and Harak, 1998). It was reported that weed interference on crop is not the same in various growth and development stages; therefore weed-crop competition capability is different in their life cycles (Tollenar *et al.*, 1994). The time of weed emergence is relatively important in determining yield losses and one of the most likely reasons has to do with the initial size difference between crops and weed seedlings. The seeds and seedlings of crop species tend to be larger than those of most weeds and it is this initial size difference that helps the crop plant to gain a competitive advantage over the weeds and pre-empt resources needed for growth and development (Gallandt and Weiner, 2007). In fact, even a small advantage in size early in the growing season can translate into a significant advantage later on. As time progresses, a plant that is only slightly larger than its neighbor can suppress the growth of that neighbor through shading because of its ability to simultaneously access photosynthetic light for itself and restrict its neighbor plant through shading. In contrast to soil resources like water or nutrient, light is a directional resource and it can be pre-empted by which ever plants grows taller and put out the most leaf area. This competition is asymmetric because the plant that is being shaded (typically the weed) has little or no ability to impact taller plant's access to light (Schwinning and Weiner, 1998). However, this asymmetric competition is progressively increased as the crop canopy closes and light becomes the most important factor limiting plant growth and development.

Adigun (2009) and Ahmed *et al.* (2012) reported 50-60% and 75% reduction in potential roselle fruit yield in response to unchecked weed. Lagoke *et al.* (1981b) reported a fibre yield loss of 59%, while Kuchinda *et al.* (1991) observed fibre and capsule yield reductions of 47.2% and 30%, respectively, due to unchecked weed growth throughout the crop life cycle on kenaf in Nigerian savanna. Kuchinda (1998) reported that, weed infestation throughout the crop growth cycle resulted in 28.2% to 53.0 wood yield, 26.5% to 55.3% fibre yield and 1.9 to 63.8% seed yield reduction of kenaf compared to the highest yield obtained in 1993, 1994and 1995, respectively. However, maximum seed yield were obtained from plants kept weed free for 9 and 12 weeks and until harvest. The seed yield reduction from the potential yield as a result of unchecked weed growth were 23%, 51% and 64% in 1993, 1994 and 1995, respectively (Kuchinda, 1998). Fibre yield reduction of 59% and 47.2% from potential yields as a result of weed infestation in kenaf were also reported by Lagoke *et al.* (1981a) and Kuchinda *et al*. (1991), respectively. Katung (1997) also reported a reduction in yields of fibre, seeds and cork of kenaf by 52.9%, 67.8% and 58.2%, respectively as a result of weed infestation throughout the crop life-cycle.

Similarly, unchecked weed growth in kenaf was earlier reported to cause fibre yield loss of 32.9% compared with maximum obtained in a trial (Lagoke *et al.,* 1981b). Katung (1997) observed that the initial weed infestation for the first three weeks after sowing did not adversely affect kenaf growth, yield and yield components, and observe that at the early stages of growth the weeds were too young and therefore not yet established to compete seriously with crop plants. In addition, at the initial growth, both the crop and weeds had adequate amount of light, nutrients, space and water relative to their requirements, hence the crop was not adversely affected. Weed infestation until 6WAS and beyond further depressed crop growth characters, yield components and yield of fibre, seed and cork compared with crop which was weed infested for 3WAS only. Katung (1997) also observed that, keeping the kenaf plant weed free for three weeks after sowing only gave similar number of capsules with the weed infested crop throughout its life cycle. The highest increase in fibre, seed and cork yields occurred when the kenaf was kept weed free between 3 and 6WAS and 9 and 12 WAS, respectively (Katung, 1997). The highest reduction in fibre, seed and cork yields of 175.0, 123.3 and 266.7kg/ha, respectively, were obtained when kenaf was weed infested from 3 and 6WAS (Katung, 1997). Katung (1997) also suggested that, the period between 3 and 6 WAS is most critical period for weed competition in kenaf when the crop is most susceptible to weed interference. Douti (1997) reported that, the first few (4-7) weeks after planting crop weed competition has the greatest effect on cotton yield. Adejonwo *et al.* (1989), Melifonwu (1999) and Olabode (2004) found out that, uncontrolled weed growth throughout the crop life-cycle reduced okrayield by 88 to 93% compared to weed free crop. Adeyemi *et al.* (2015) also reportedthat uncontrolled weed infestation in okra led to 89.31 and 87.28% pod yield reduction in early and late season crops, respectively.

Saeed and Koroush, (2008) reported that periodical weed interference had no influence on 1000 seed weight and number of seed/pod on lateral branches but caused significant reduction on pod number on main, lateral branches and seed number/pod on lateral branches and seed number/pod on main shoot with increasing weed interference duration.

Seed yield was significantly affected and decreased by weed interference duration exceeding on Wintercola (*Brassica napus* .L.).

2.3 Critical Period of Weed Interference on Roselle.

The critical period of weed interference refers to the minimum amount of time during which a crop must be kept free of weeds in order to prevent yield loss (Nieto *et al.,* 1968). It can also be described as the early period of crop growth when weeds need to be controlled to prevent yield reduction (Zimdahl, 1980). The critical period for weed interference is overlap by two components: the minimum free period and maximum weed infested period (Ghoshen *et al.,* 1996). It represents the time interval falling between two separate components: the minimum length of time after seeding that a crop must be kept weed free so that later emerging weeds do not reduce yield and the maximum length of time that weeds which emerged with the crop can be ignored before they can cause detrimental competition for growth resources. The former relates to the required length of residual activity for a soil-applied herbicide and the latter to the optimal timing for post-emergence weed control. Weeds which are present before or after this period will notgenerallyaffect yield. If these two components overlap, there will be no critical period, and a single weed control operation would be adequate.The critical period for weed control have been determined by several workers in field crops (Robert, 1976; Frisen, 1979; Weaver and Tan, 1987, Van Acker *et al.,* 1993) on vegetable crops. This period has been determined for a number of crops and can be used to optimize the timing of weed control practices (Robert, 1976; Dawason, 1977; Friesen, 1979; Weaver, 1984).

Lagoke *et al*. (1981b) estimated thatthe critical period of weed competition in kenaf was between 3 and 4 WAS. Douti (1997) evaluated that the first few (4-7) weeks after planting crop weed competition has the greatest effect on cotton yield. Katung (1997) and Kuchinda

(1998) reported that the critical period of weed interference in kenaf was between 3 and 6 WAS. Nieto *et al.* (1968) observed that in most vegetable crops, the greatest yield reduction due to weed interference occurred during this critical period. Farmers wrongly assume that weed competition problem is solved by removing weeds at anytime during the growing season (Zimdahl, 1980). For most crops weed competition or interference during the first quarter of growth period was observed to be very critical because the damage to crop at this stage was irreversible. If such damage could be avoided during this early period, subsequent weed growth is unlikely to have significant effect on yield. In vegetable crops, the first one third of a crop life-cycle has to be kept weed free if adverse effect of weeds on yield are to be avoided.

The study of critical period of weed control can be used to determine weed control strategies and to explore the nature of weed-crop competition. An important contribution to management of the critical period of weed competition in crops is the development of alternative weed management strategies (Weaver and Tan, 1987; Swanton and Weise, 1991).

2.4. **Chemical Weed Control on Roselle.**

The control of weeds accounts for 20-60% of the cost of production, depending on ecology and crop types (Onyinbe and Shebayan, 2013). Poor weed control can cause 35-60% yield losses in crops. Weed control among peasant farmers is labour intensive and relies on human labour which is declining in Nigeria. There is therefore the quest for labour saving, efficient and cost effective ways of weed control (Onyinbe and Shebayan, 2013).The growth of weeds in some field crops, likewise in roselle, especially during the early seedlings establishment affects the plant and causes heavy losses. Calyces yield in roselle is highly correlated with vegetative growth, which is retarded if there is abundant weed growth. Adequate weeding is therefore essential at this critical stage of weed competition after which roselle is able to produce canopy that will suppress any later emerging weeds. A weed control method effective in particular conditions may not be feasible or effective in other set of conditions (Muhammad *et al*., 2013). According to Lagoke *et al*. (1998), a total number of 309 man-days are required to hand weed one hectare of maize compared to 91 man-days needed for herbicide application and supplementary hoe-weeding. The scarcity, high cost and scarcity of labour at the period of operations render both manual and mechanical weeding difficult, thus emphasizing the need for herbicide use.The problem associated with manual and mechanical weed control can be addressed by the use of herbicides which have been found to reduce labour requirement and its attendant cost, facilitate effective weed control and also increase profitability in crop production (Sinha and Lagoke, 1984).Tunio (2000) reported that, weeds population and losses could be minimized through better weed control. Effective and economic weed control is essential as weeds are the most efficient users of resources due to their different kinds, intensity and fast growth habits (Dilbaugh *et al*., 2014). El-Deed *et al*. (1984) reported that, chemical weed control was more effective and gave higher cotton yield than hand weeding. Khan *et al*. (2001) reported that, application of pendimethalin and oxadiazon significantly reduced the weed density and increased the number of bolls per plant and seed yield of cotton.

In Nigeria, the use of herbicide has been reported to be more profitable than hoe-weeding (Sinha *et al*., 1982; Bakut, 1985; Ogungbile and Lagoke, 1986, Lagoke and Shebayan 1988). Chemical weed control is more adapted to large scale crop production than other weed control method, and it is labour saving (Anon, 1994). Many herbicides have been reported for chemical weed control in roselle, and these include Galex (metolachlor + metobrumuron) and Ronstar (oxadiazon) (Adigun, 2009). Other herbicides include Codal (metolachlor + metobromuron), Ronstar (oxadiazon) and Stomp (pendimethalin) (Adekpe and Adigun, 2000).Adigun (2009), reported that application of metolachlor + metobrumuron at 1.0 + 1.0kg a.i/ha followed by the supplementary hoe- weeding resulted in effective weed control with high crop vigor, more number of leaves and fruit yield /plant, heavier fruit weight and these were comparable to the plot hoe-weeded three times in roselle. Application of metolachlor+ metobrumuron + metolachlor (Galex) at 2.0 kg a.i /ha and (pendimethalin) Stomp at 1.0 and 1.5kg a.i /ha resulted in higher crop vigor and fruit yields of roselle that were comparable to two hoe-weeded in the two years of trials (Adekpe and Adigun, 2000). Mohammed *et al*., (2012) reported that the application of pendimethalin at low rate of 1.5 kg a.i /ha could provide alternative weed management to hoe-weeding for good vegetative growth in roselle.

There is paucity of information on the use of chemical weed control in roselle production, and so related crops such as kenaf, cotton and okra were used in this review since they are from the same *Malvaceae* family. Application of pendimethalin at 1.0kg a.i /ha resulted in higher growth of okra and could provide alternative weed management to hoe-weeding (Hammaand Ibrahim,2012).Also, Haruna *et al.* (2012) reported that, application of metolachlor and pendimethalin each at 1.0 kg a.i /ha gave better weed control and higher yield of okra that was comparable to weedy check which depressed the yield. Kuchinda *et al*. (1991) and Kuchinda (1998) observed that ametryne in mixture with either alachlor or metolachlor performed well than when individual herbicide was applied alone. Lagoke *et al*. (1981b), Kuchinda *et al*. (1991) and Kuchinda (1998) have also reported that, alachlor and mixture of norfluron with ametryn or diuron gave selective weed control as well as increased fibre yield in kenaf in the Nigerian savanna. Fageiry (2008) reported that, application of pendimethalin both pre-planting and pre –emergence application each at 1.2

to 2.4kg a.i /ha gave effective weed control on kenaf and further expantiated that, application of oxadiazon and its tank mixture with diuron were considered to be toxic for recommendation to kenaf grower. Akobundu (1987) reported that fluchloran, fluometuron, prometryn, trifluralin and mixture of norflurazon with diuron gave selective weed control as well as increase fibre yield in kenaf.

Gestate (ametryn + prometryn) at less than 2.5kg a.i /ha and alachlor at less than 31/ha applied pre-emergence caused 15.20% yield losses while application of diuron, monolinuron and flumeturon caused yield losses of up to 50% in kenaf. Application of ametryne with alachlor at 1.0 + 1.5 kg a.i/ha, ametryne + metolachlor at 1.0 + 1.5 kg a.i/ha and pree with metolachlor at 1.0 + 0.75 kg a.i/ha gave an effective weed control up to 6WAS and high yield of fibre, seed and cores in kenaf (Katung,1997). Orsenigo, (1964) reported a 50% stand reduction during pre-emergence application of diuron at 3.0 kg a.i /ha on kenaf from granular and sprayable application. White *et al*. (1970), Hickman and Scot (1989) reported metolachlor at 3.4 kg a.i /ha provided excellent grass control and acceptable broad-leaves weed control with no reduction in stand count on kenaf. Kurtz and Neil (1992) stated that application of metolachlor at 3.0 kg a.i /ha gave no visual injury to kenaf. Kuchinda (2012) evaluated two formulation of diuron, on cotton and the result obtained showed that the use of low rate of the powder (1.2kgWP/ha) and Liquid (1.0Sc/ha) formulations followed by supplementary hoe-weeding could be recommended as an integrated weed control strategy in the Northern Cotton Zone (North West) of Nigeria. The high rate of each formulation resulted in unknown yield loss, which affected maize crop in rotation. Tunio *et al*. (2003) reported that, application of metolachlor and pendimethalin as pre-emergence herbicide for effective weed control method for cotton. Mahar *et al*. (2007) stated that, application of pendimethalin at 5l/ha reduced weed density significantly (91.59) over other weed control measures which in turn resulted in taller plant (155.60cm), exhibited more fruiting branches(13.50per plant) higher productive bolls (80.78per plant) and maximum seed cotton yield (1957.50kg/ha). Ali *et al*. (2005), Deshpande *et al*. (2006) reported that maximum increase of 199.4% in seed cotton yield was obtained with pendimethalin which resulted in 89% and 90% broadleaf and grass weed controlled. Clewis *et al*. (2008) observed that heavier lint yield of cotton was obtained with the application of metolachlor.

2.5 Test Herbicides.

2.5.1 Pendimethalin (Stomp 50% EC).

The chemical name is N-(1-ethylpropyl) 3, 4-dimethy-2, 6-dinitrobenzenamine, the IUPAC name is N-(1-ethylpropyl) -2,6-dinitro-3.4-xylidine and chemical formula is $C_{13}H_{19}N_3O_4$. It is a member of Dinitroaniline class of herbicides.It has orange-yellow colour with melting point of 54-58^{0}C, vapour pressure 1.94mPa (25^{0}C) specific density 1.19 (25^{0}C). Its solubility in water is 0.33mg/l (20^{0}C), in acetone 800, xylene >800, hexane 48.98, dicholoromethane>800 (all in g/l, 20^{0}C). It is readily soluble in benzene, toluene and chlorofoam, and slightly soluble in petroleum, ether and petrol. It is very stable in storage, stores below 1.30^{o}C and above 5^{0}C stable to acids and alkaline. It is slowly decomposed by light. It has field half-life of 44days, which may vary with temperature and soil moisture condition.

Pendimethalin was discovered in 1971 by American Cyanamid, first reported in 1974 and registered for cotton, maize, tobacco, sorghum, wheat, peanut, sunflower, rice, sugarcane etc. It is applied pre or early-post-emergence at 0.50 to 2.0kg/ha in aforementioned crops. It can also be used for crop such as potato, onion, vegetable and fruit crops. It controls primarily, annual grass weeds such as *Seteriaspp*, *Echinochloa crus-galli*, *Panicum dichotomifloran*, *Digitariaspp*, *Sorghum halepense*, *Brachiaria spp*, *Abutilon theophrasti* and broad leaf weeds such as *Amaranthus retroflexus*, *Kochiascoparia* and *Solanum nigrum*. It can be mixed with Imazapyr, Imazaquin and oxyfluorfen(Rao, 2004)..

2.5.2 Oxadiazon(Ronstar)

Oxadiazon commonly called Ronster, is a member of Oxadiazole class of herbicides. It has chemical abstract name 3-(2, 4-dichloro-5-(1-methylethoxy) phenyl)-5-(1,1-dimethylethyl]-1,3,4-oxidiazol-2-(3H)-one. It is primarily used as pre-emergence herbicide 0.5-4.0kg/ha although it shows some post-emergence activity at 0.5-2.0kg/ha. It is used in rice, cotton, sugarcane, soybean, groundnut, onion, garlic, potato, sunflower, transplanted vegetables, tea, rubber and banana. It is particularly useful in controlling weeds that grow from bulbs, rhizomes and other deep rooted plant propagules, including *Cynodon dactylon*, *Loliumperenne* among others. It is effective against many annual broadleaf and grass weeds such as *Oxalis* spp, *Amaranthus spp*, *Urtical spp*, *Poa annua*, *Digitaria spp*, *Mallugoverticillata*, *Cenchrus incertus, Eleusine indica and Setaria viridis*. The application of Oxadiazon as post-emergence treatment is active during the early growth stage of weeds. Oxaidiazon has moderate to long persistence, with a field half-life of 60days (Rao, 2004).

2.5.3 Metolachlor.

Metolachlor was synthesized in 1976 by Ciba-Geigy. It is a member of Chloroacetanilide class of herbicides. The common name is metolachlor and the chemical name is 2-Chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxyl-1-methylethyl) acetanide. It can be applied early pre-planting, pre-emergence or early post-emergence at 1.5-4.0kg/ha in maize, pre-emergence at 1.0-2.0kg/ha in cotton, 1.5-3.0kg/ha in groundnut, sorghum, sunflower, soyabean and potato. Pre-planting, post-emergence at 1.5 -3.0kg/ha on groundnut, pre at 1.5-3.0kg/ha in sorghum, sunflower and soyabean and pre-planting, pre or after hill formation at 1.5-3.0 kg/ha in potato. Metolachlor controls many annual weeds such as *Cyperus esculentus, Setaria spp, Echinochloa crus-galli, Digitaria spp, Panicum dichotomiflorum, Brachiaria spp, Panicum capillare* etc. It also controls certain broadleaf weeds such as *Amaranthus retroflexus, Mollugo verticillata* (Carpet weed) etc. It can be applied in liquid or dry bulk fertilizer. Metolachlor can be mixed with altrazine, cyanazine, metribuzin etc. when applied alone; it provides weed control for 10-14 weeks. Field half-life is 3-5 month, but residues do not persist long enough to affect crops planted in the following season (Rao, 2004)..

2.5.4 Butachlor.

It is a member of chloroacetanide class of herbicides and is the herbicidal active ingredient in MACHETE^{R} EC. The common name is Butachlor, and chemical name is 2-Chloro-2, 6-diethyl-N-(butoxymethyl) acetanilide. The molecular formula is $C_{17}H_{26}NO_2Cl$, has molecular weight of 311.9 and melting and vapour pressure of 4-5^{0}C and 1.8x10^{-6} mmHg at 25^{0}C respectively. Its water solubility is 20ppm at 25^{0}C and it can be mixed with alcohol, ether, acetone and other organic solvents. It has no distinctive sign of toxicity. It is applied in irrigated rice within 2-5days of transplanting of seedling. It can be applied 10-15 days after sowing directly seeded irrigated rice. Butachlor is used in several other crops like groundnut, potato and soybean, and other pulses grown under irrigated or assured rainfall conditions. It is very effective against annual grass weeds such as *Echinochloa crus-galli, Digitaria sanguinalis, Setaria spp, Panicum spp* and certain sedges. Its field half-life is

30days. It provides weed control for 4-7 weeks and does not injure crop in the following season. Butachlor is synthesized by buthoxy methylation of the appropriate acetanilide (Rao 2004).

2.5.5 Diuron.

Diuron (Karmex^R). The chemical class name is Ureas and has chemical abstract name (N-(3, 4-dicholorophenyl)-N,N-dimethylurea). It can be applied pre-emergence at 0.8-2.5kg/ha for controlling emerging grass and broadleaf weed seedlings in tea, cotton, coffee, grapes, pineapple, apples, pears, citrus and other plantation and orchard crops. It can also be applied as post-directed spray in maize, sorghum at 0.2-0.4kg/ha. It can be used to formulate post mixture with MSMA, paraquat, bromacil, dichlorobenil, tebuthiuron, sodium metaborate, sodium chlorate,2,4-D and Imazapyr. Diuron controls many annual weeds at lower rates and certain perennial weeds at higher rates. It is readily absorbed by roots, less so by foliage and stems. It is translocated rapidly from the roots via the xylem. Little to low diuron moves basipetally out of the treated leaf via the phloem. Average persistence of diuron in the field is 90days. Phytotoxic residues within a season when applied at lower selective rates. At higher rates, residue may persist for more than one year. Diuron is moderately leachable with non-significant losses to volatilization, except when exposed on the soil surface for several days or weeks under hot, dry condition. (Akobundu, 1987; Rao 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

Two field trials were conducted during each wet seasons of 2011 and 2012, at the research farms of the Institute for Agricultural Research, Samaru (Lat. 11^0 11^1, Long. 07^0, 38^1; 686m above sea level) and at the Federal College of Forestry Mechanization,ForestryResearch Institute of Nigeria, Afaka (Lat 10^0, 03^1, Long. 07^0, 21^1; 644m above sea level), both in the northern Guinea savanna zone of Nigeria. The experimental site at Samaru had been under continuous cultivation for years with arable crops such as groundnut, maize, guinea-corn and okra; while that of Afaka had not been cultivated for quite a long time.

3.2 Soil Analysis

The soils of the two experimental sites were taken for analysis prior to the establishment of the trials in 2011 and 2012 to determine their physical and chemical properties. At each location, soil samples were taken at random locations at the depth of 0-30cm using a soil auger. The samples were air-dried and thoroughly mixed, ground and passed through a 2mm sieve and then subjected to routine laboratory analysis. Soil physical, chemical properties as well as particle size distribution were determined using standard procedure as described by Jackson (1973); Okalebo *et al.*(1993) and Sparks (1996). The textural class of soil was determined by the use of USDA soil textural triangle.The results obtained are presented in Tables 1 and 2.

3.2.1Particle size analysis

Particle size analysis was determined by the hydrometer method. In this method, 100ml of Calgon solution (Sodium hexametaphosphate) was added to 50g of soil samples and stirred (Day, 1965).

3.2.2 pH determination

The pHof the soil was determined by potentiometer in 1:1 soil solution using p^Hmetre. A sample of 10g of the air-dried soil was weighed through 50ml beaker and 20ml of distilled water was added to one beaker and the second beaker with 20ml of 0.01m $CaCl_2$ solution. The electrode of the pHmetre was inserted into partly settle suspension and reading was taken from the galvanometer.

3.2.3 Organic carbon (gkg^{-1})

Organic carbon was determined by the acid dichromate wet oxidation technique of (Walkey and Black, 1934). The method involved the digestion of soil organic matter by potassium dichromate ($K_2Cr_2O_7$) using concentrated Sulphuric acid to increase the temperature and hasten the reaction. One grams (1g) of the soil was weighed into a 250ml flask, 10ml of $K_2Cr_2O_7$ solution was added and gently disperses 20ml of concentrated Sulphuric acid was then added and content of the flask mixed by gentle rotation.

The reaction was left on for 30minute after the mixture was diluted to 250ml distilled water excess dichromate was back titrated with ferrous ammonium sulphate using Barium dichromate diphenylamine sulphate as indicator. Blank were also determined using all the steps mentioned above without soil sample to standardize the dichromate Blank (1965).

3.2.4 Available phosphorous (P; mg kg^{-1})

Available phosphorous was determined by Bray No.1 method, (Bray and Krutz, 1945). One gram (1g) of soil sample was weighed into 15ml centrifuge tube and 7ml of extracting solution was added. Phosphorous was determined in the extract calorimetrically using ascorbic acid molybdate blue, and reading was taken.

3.2.5 Total soil nitrogen (gkg^{-1}).

Total soil nitrogen was determined by macro kjeldahl procedure (Bremmer, 1965). Five grams (5g) of finely ground sample of soil was weighed into a 50ml kjeldahl digestion flask and 1g of potassium sulphate catalyst mixture and 3ml of concentrated sulphuric acid were added. The flask was gently heated on a digestion rack until a clear digest was obtained, and then the mixture was boiled for another 3 to 5 hours. The flask was allowed to cool, 20ml of distilled water was added in order to bring all the material into suspension, then transferred the whole digest to kjeldahl distillation flask and make sure 50ml and 80ml marks have been pre-determined in the flask. The kjedahl digestion flask was rinsed three times with about 9ml of distilled water, this was placed in a 5ml of Boric acid (H_3BO_3) as an indicator solution into a 50ml Erlenmeyer flask marked to indicate a 35ml level, 20ml of 10N Sodium hydroxide was added to the funnel of the distillation apparatus and washed down the funnel with 15ml of distilled water and allowed to run into the distillation flask with distilled water. The distillation was started immediately by closing the stem of the bypass tube at the base of the distillation apparatus. When the distillate reached 35ml on the flask, the stem of the pass tube was opened, then the end of the condenser was reached and determination of N was obtained by titrating with 0.1N HCl or H_2SO_4

3.2.6 Exchangeable bases ($cmol_+kg^{-1}$)

Exchangeable bases were determined by 1N ammonium acetate NH_4OAC (p^H 7.0) saturation method. A sample of 10g of soil sample was weighed into 500ml Erlenmeyer flask and 40ml of neutral 1N NH_4OAC was added. The flask was shaken thoroughly and it was allowed to stand overnight. The mixture was filtered by using filter paper and was leached with 1N NH_4OAC to obtained calcium test a few drop of 1N NH_4Cl, 10% ammonium oxalate and dilute NH_4OH were added to 10ml of the leachate in a test-tube and the solution was heated to near the boiling point. The presence of calcium was indicated by white precipitate.

Test for magnesium, potassium and sodium was done by using a flame photometer.

3.2.7 Cation exchange capacity. The soil was leached four times with 1N ammonium chloride (NH_4Cl) and once with 0.25N (NH_4Cl), (25ml of each was used). The electrolyte was washed with 200ml of 99% ethyl alcohol; the soil was allowed to drain thoroughly. The soil and filtrate were transferred into 500ml kjeldahl flask and 200ml of distilled water and few drops of liquid paraffin pumice beads were added to prevent fuming and bumping 10ml of 1N NaOH. Then 60ml of the solution was distilled into 50ml of 2% boric acid solution measured into a 250ml Erlenmeyer flask, 10 drops of bromocresol green- methyl red mixed indicator was added and it was titrated with ammonium borate produced with standard 0.02N H_2SO_4. Blank of the reagent was prepared to serve as control without soil sample. The colour change from bluish green through bluish purple to pink at the end point. The reading was taken to calculate the milli equivalent of ammonia in 100g of soil.

3.3 Meteorological Data

Data on rainfall, sunshine hours, temperature and relative humidity for the two experimental sites during the periods 2011 and 2012 were obtained from meteorological station of the Institute for Agricultural Research, Samaru and Federal College of Forestry Mechanization, Afaka, Kaduna. The results are presented in Appendices (I-IV).

3.4 Treatments, Experimental Design and Plot Size

Two experiments were carried out under this study as follows:

3.4.1 Experiment I: Weed control study

The weed control experiment had a total of fourteen treatments consisting of five herbicides, each evaluated at two rates: metolachlor, butachlor, oxadiazon, pendimethalin each at 1.5 and 2.0 kg a.i/ha and diuron at 2.0 and 2.5 kg a.i/ha, and hoe-weeding (HW) at 4;(HW) at 3 and 6; (HW) at 3, 6 and 9WAS and a weedy check. The treatments in the two locations were laid-out in a Randomized Complete Block Design (RCBD) and replicated three times. The gross plot size was 3m x4.5m (13.5m^2) with six rows of three (3m) long while net plot size was 3mx3m (9m^2) with four rows. An alley of 1m across and 1 ridge along the ridges were left between plots and replicates.

3.4.2 Experiment II: Weed interference study

The experiment was aimed at studying the effect of period of weedinterference on growth and yield of roselle (*Hibiscus sabdariffa* L.*).* The treatments consisted of ten periods of weed interference in two sets: In the first set, plots were initially kept weed free by hoe-weeding for 3, 6, 9 and 12 weeks after sowing (WAS) and left weed infested thereafter. In the second set, plots were left weed infested initially for the corresponding periods and kept weed free thereafter. There were two controls: plots kept weed free throughout the crop life cycle and plots left weed infested throughout the crop life-cycle. The treatments in the two locations were laid-out in a Randomized Complete Block Design (RCBD) and replicated three times. The gross plot size was 3m x 4.5m (13.5m^2) with six rows of three (3m) long while the net plot size was 3m x3m (9m^2) with four rows. An alley of 1m across and 1 ridge along the ridges were left between plots and replicates.

3.5 Cultural Practices.

3.5.1 Land preparation

In both yearsof thetrials, the land at each location was harrowed twice and ridged, 75cm apart. It was marked out into experimental plots, each measuring 3m by 4.5m with six ridges of 3m long.

3.5.2 Cultivar description

The roselle seed used in this experiment Ex-Zaria sourced from the Institute for Agricultural Research, Samaru. It is of medium height with a profuse branching habit with dark stem, petiole and leaf midribs. The cultivar produces high quality calyces preferred by consumers and marketers. It is drought tolerant and matures in 4 -5 months, and has average seed yield of 900kg/ha (Kumar *et al*.,1985).

3.5.3 Seed treatment

Before planting, the seeds were treated with Apron Star ^{R} (10% metoxyl; 6% carboxyl and 34% furathio carb at the rate of 10g per 4kg of seed. This became necessary in order to prevent soil borne diseases, protect from seed rot and seedling blight, and improve germination that would enhance better stand count and soil pests and diseases control.

3.5.4 Planting

Five seeds of roselle were manually sown per hill on the ridges at intra and inter row spacing of 50 cm and 75 cm, respectively. The plants were later thinned to two plants per stand at two weeks after sowing (WAS). Planting was done on 12th and 13th July, 2011 and 7th and 8th July, 2012 at Samaru and Afaka, respectively.

3.5.5 Herbicide application

In the weed control experiment, the herbicides were applied pre-emergence, one day after seed sowing using a knapsack (CP3) sprayer in a spray solution 200L/ha and pressure of 2.1kg/m^2 using a green deflector nozzle according to the treatments.

3.5.6 Fertilizer application

In each experiment, fertilizer NPK 20: 10: 10 was applied at the rate of 300 kg/ha by banding, 5cm away from each seedling and 2.5cm deep in two equal split doses at 2 and 6WAS.

3.5.7 Hoe-weeding

Hoe-weeding operation was carried out according to the relevant treatments. Before this was done, weed samples were collected from $0.25m^2$ in each plot using quadrant.

3.5.8 Weed types/composition

The weeds identified were classified into grasses, broad -leaves and sedges and scored according to their level of infestation as presented in Tables 3 and 4.

3.5.9 Insect pest control

Common insects pests observed in the crop identified included Aphids, flea beetles and white flies which were controlled using Karate 500EC (Lambdacyhalothrin) at the rate of 25ml per 15litre of water and applied with CP 15 knapsack sprayer with white deflector nozzle. Spraying commenced from four weeks after planting with four weeks intervals and stopped two weeks before harvesting as a routine preventive measure against pests.

3.5.10 Harvesting and processing

The plant reached full physiological maturity at four-five (4-5) months (16-20 WAS) (Nov-Dec) and ready for harvest when most of the leaves were shedding and lower capsules on the stem began to split open. At this stage the seed in the capsule had turned reddish brown and calyces were fully expanded. The net plots were carefully harvested by cutting the plants from the base with a sharp cutlass and placed in a plastic bucket according to the treatment. The calyces were then separated from the capsule by hand, air-dried and weighed. The capsules were also shelled to obtain the seeds which were then weighed.

3.6. Observation and Data Collection

3.6.1 Weed parameters

Weed cover score.

Observations were taken visually at 3, 6, 9 and 12WAS. A scale of 1 to 9 was used to assess the level of infestation, where 1 represented no weed cover and 9 represented complete weed cover.

Weed dry weight

Weed samples were collected from 0.25m^2 area quadrant per plot before each weeding operation at 3, 6, 9 and 12 WAS. The weed samples were cleaned free of soil and debris oven-dried at a temperature at 70^{0}C until constant weight was obtained. Dry weight was determined using Denver electronic digital scale Model XP 300, weighing at 0.01g precision. The mean weight was recorded in g/m^2

Weed control index

It is derived parameters and compares different treatments of weed control on the basis of weed dry weight. This was obtained using the formula by Misra and Tosh (1979).

$$WCI = \frac{(WDWc - WDWt)}{WDWc} \times 100$$

Where WDWc is the weed dry weight {unit/m^2} in control plot; WDWt is the weed dry weight {unit/m^2}in treated plot. This was measured at 3, 6, 9 and 12WAS

Herbicide efficiency index

This was calculated using the formula of Krishnamurthy *et al.*(1975 and it is given below:

$$HE = \frac{\frac{(YT - YC)}{YT} \times 100}{\frac{WDWT}{WDWC} \times 100}$$

Where, YT is crop yield from the treated plot; YC is crop yield from the weedy check; WDWT is weed dry weight in the treated plot; and WDWC is weed dry weight in the weedy check plot. This was obtained by using weed dry matter at 12WAS. This was taken for only experiment one in the two locations.

3.6.2 Crop growth and yield characters.

Assessment of growth characters was carried out at 3, 6, 9 and 12 (WAS) on five randomly selected plants and tagged within the net plot

Seedling emergence %: -

This was done by counting the emerged plants as percentage of planted/hole.

*Crop injury score***.**

This was assessed by visual assessment at 2WAS using a scale of 1-9, where 1 represented no crop injury and scale 9 scored completely death plants. Features of the plants used for scoring were leaf size, color and height of the plant.

Crop vigour score.

The vigour of plants in each plot was assessed on visual scale of 1-9, where 1 represented unhealthy crop with dead plantsand 9 the most vigorous plants. In visual assessment, plant height, stem thickness, foliage greenness and canopy spread were taken into consideration

Plant height (cm).

Heights of five tagged plants within each net plot were measured using a graduated meter ruler from the basal ground level to the tip of the youngest plants at all sampling periods and mean height per plant recorded.

*Number of leaves /plant***.**

This was carried out by counting the total number of fully opened leaves on the tagged plants and the mean per plant computed.

Stem girth/plant: - The diameter of each tagged plants was measured using vernier caliper to determine the stem diameter at the base of each tagged plant and the mean per plant computed and expressed in (mm).

Number of primary branches/plant.

This was carried out by counting the number of branches borne on the main stem of each tagged plant and the mean per plant recorded.

Number of secondary branches/plant: - This was carried out by counting the number of branches borne on primary branches of each of the tagged plants and mean per plant computed.

Number of tertiary branches/plant: - This was carried out by counting the number of branches borne on secondary branches of each of the tagged plants and mean per plant computed.

Number of days to 50% flowering:- This was done by monitoring, counting and recording the number of days to flower initiation and attainment of 50% flowering of the plants in each plot This was also documented.

Days to physiological maturity: - This was determined by counting the number of days from sowing to physiological maturity and ready for harvesting. During this time the leaves were shedding and lower capsule had begun to split open.

Stand count at harvest %: This was obtained by counting the number of stand/hole at harvest and mean per plot recorded.

3.6.3 Yield and yields components.

Samples of five plants were taken at random from the net plots at maturity to measure the following yield and yields components.

*Number of dry calyces/plant***:-** Total number of harvested calyces was counted from five randomly selected plants in each net plot and mean per plant computed.

Calyx dry weight/plant **(g):** - The calyces of the five plants above were peeled off from the capsule using simple hand tools. The calyces were air- dried to constant weight, and the mean calyx's weight per plant was determined and expressed in (g).

*Calyx yield kg/ha***:-**The calyces weighed per plot were extrapolated to yield in kilograme/hectare (kg/ha).

*Number of seed/capsule***:-**Ten (10) capsules were randomly selected from tagged plants in each net plot and the seeds were shelled out from the capsule and counted, and mean recorded.

Seeds weight/capsule:- The seeds obtained from ten selected capsule randomly were weighed and mean weight computed, recorded and expressed in gram/capsule

*100 seeds weight***: -** This was determined by randomly selecting 100 seeds from each net plot, weighing and the mean recorded and expressed in gram/100 seed weight.

3.7 Proximate Analysis: Cleaned calyces from each net plot were analyzed for their chemical constituents. The chemical constituents analyzed include: Vitamin C, B^1, B^2, Bcomplex, and % protein which were analyzed in the department of Animal Science while Calcium and Iron were carried out in the department of Soil Science both in Ahmadu Bello University, Zaria. The fat, fibre and ash were performed inNational Raw Material Research Institute of Chemical Technology, Zaria.

3.8 Statistical Analysis

The data collected were subjected to analysis of variance to determine effect of treatments on measured characters as described by Snedecor and Cochran (1967). The treatment means were compared using the Duncan's Multiple Range Test (Duncan, 1955). The relationships between calyx yield and other characters were determined using simple correlation analysis as suggested by Little and Hills (1978). The regression analyses were carried out to determine the critical period of weed competition in two sections and in the combined using regression analysis as described by Steel and Torrie, (1984).

3.9 Economic Analysis

This was done by obtaining information on the cost of all cultural practices from land preparation to harvestingfrom personal survey, Institute for Agricultural Research Samaru, Zaria, and Kaduna Agricultural Development Project, Kaduna.The current prices of equivalent 1kg were obtained from open market in Samaru (Zaria) and Kawo (Kaduna) to calculate total revenue. The economic evaluation was done for different herbicides and rates compared with hoe-weeded control and a weedy check and on various periods of weed interference. This was done in order to obtain the most cost effective and profitable treatment for the production of roselle. Partial farm budget was adopted from Okoruwa *et al*. (2005) for economic evaluation. The mathematical expression of it is given as;

$$GM = TR - VC$$

$$TR = Y_1 \times P_1$$

$$VC = M + L$$

Where : GM = Gross margin

TR = Total Revenue, VC = Variable Cost

Y_1 = Roselle yield /ha , P_1= Price of roselle yield

L = Value of labour (Land preparation, planting, weeding, herbicide, insecticide application, harvesting and transportation).

M = Value of material input (seed, fertilizer, polybags, insecticide and herbicides.

CHAPTER FOUR

4.0 RESULTS.

4.1 Soil Physical and Chemical Properties at Experimental Sites.

The characteristics of soil in the two locations and years are shown in Tables 1 and 2. The soil textural class at Samaru and Afaka in 2011 was sandy loam, clay loam and loam in 2012. The soil pH in water at Samaru ranged from 4.96 and 4.97 in 2011, and 5.70 and 5.0 in 2012, while at Afaka it ranged from 6.40 - 6.00 in 2011 and 6.20 - 6.30 in 2012. The soil was moderately acidic at Samaru and slightly acidic at Afaka. The soil was very low in organic matter, total nitrogen in the two years of study at both locations but high in available phosphorous at both location. The exchangeable bases were also low but the cation exchange capacity (CEC) was moderate. The soils were generally low in inherent soil fertility and this was consistent with the nature of soil in the northern Guinea savanna.

4.2Common Weeds Species in the Study Areas (Both Locations).

The major weeds in the study areas were identified and classified into grasses; broad-leaves weeds and sedges (Table 3). In 2011 at Samaru, *Heteropogon contortus* and *Panicum maximum* were the grass species with high level of infestation. In 2012, *Imperata cylinderica, Eleusine indica*, *Cynodon dactylon*, *Heteropogon contortus*, *Rottboelia cochinchinensis*, and *Panicum maximum* were the grassess with high level of infestation *Commelina bengalensis* was the only broad-leave species with high level of infestation in 2011, while in 2012, *Heterotis rotundifolia* and *Commelina bengalensis* were the broad-leaves species with high level of infestation. At Afaka, in 2011 (Table 4) *Imperata cylinderica* and *Rottboellia cochinchinensis* were grass species with high level of infestation.

Table 1: Physical and Chemical Properties of Soil at the Experimental Site in Samaru During 2011 and 2012 Wet-Seasons.

Soil Characteristics	**2011**		Soil Depth (cm)	**2012**	
Particle size distribution(gkg^{-1})	0-15	15-30		0-15	15-30
Physical properties					
Clay	20	26		19	16
Silt	24	34		38	37
Sand	56	40		43	47
Textural Class	Sandy loam	Clay loam		Loam	Loam
Chemical properties					
pH Ratio					
pH in Water(1:2.50)	4.96	4.97		5.70	5.30
pH in 0.01M $CaCl_2$	4.26	4.13		5.10	4.70
Organic Carbon ($g\ kg^{-1}$)	0.41	0.31		0.62	0.54
Total Nitrogen ($g\ kg^{-1}$)	0.14	0.13		0.64	0.62
Available phosphorus (P;$mg\ kg^{-1}$)	10.85	12.72		16.5	18.0
Exchangeable bases ($cmol_+kg^{-1}$)					
Ca^{2+}	3.14	2.96		3.62	3.17
Mg^{2+}	0.30	0.27		1.58	1.52
K^+	0.143	0.152		0.72	0.96
Na^+	0.174	0.163		0.81	0.74
Exchangeable acidity					
(H + Al)	1.20	1.20		0.98	0.92
CEC	5.00	4.80		7.71	7.31

Table 2: Physical and Chemical Properties of Soil at the Experimental Ste in Afaka During 2011 and 2012 Wet Seasons.

Soil Characteristics	2011 Soil Depth (cm)		2012 Soil Depth (cm)	
Physical properties	0-15	15-30	0-15	15-30
Particle size distribution %				
Clay	16	30	10	26
Silt	16	16	32	34
Sand	68	54	68	40
Textural Class	Sandy loam	Clay loam	Loam	Loam
Chemical properties				
pH Ratio 1:250				
pH in Water	6.40	6.00	6.20	6.30
pHin 0.01m $CaCl_2$	5.20	5.40	5.10	4.80
% Organic Carbon (g kg^{-1})	0.408	0.309	0.62	0.54
% Total Nitrogen (g kg^{-1})	0.043	0.033	1.33	1.24
Available phosphorus (P;mg kg^{-1})	8.75	7.00	12.50	14.00
Exchangeable bases ($cmol_+kg^{-1}$)				
Ca^{2+}	4.00	4.00	3.35	2.83
Mg^{2+}	1.16	1.36	1.17	2.36
K^+	0.11	0.17	0.17	0.19
Na^+	0.32	0.44	0.33	0.37
Exchangeable acidity				
(H + Al)	1.30	1.30	0.95	0.90
CEC	6.89	7.27	5.97	6.65

Table 3: List of Common Weed Species and their Level of Infestation in 2011 and 2012 Wet Seasons at Samaru.

Grasses	2011	2012
Imperata cylindrica .L.P.Beauv	**	***
Eleusine indica Gaertn	**	***
Cynodon dactylon. L.pers	**	**
Ischaemum rugosum Salisb	*	**
Heteropogon contortus Roem and Schult	***	**
Digitaria horizontalis wild	**	***
Rottboelia cochinchinensis(Lous)	**	***
Panicum maximum Jacq	***	***
Panicum repens .L.	**	**
Loudetia annua C.E Hubard	**	**
Broad - Leaves Weed		
Ipomoea tribola L.	**	**
Crotalaria retusa L.	**	**
Chromolaena odorata L.	**	**
Heterotis rotundifolia (SM).Jac.fel	**	***
Commelina benghalensis L.	***	***
Corchorus olitorius L.	**	**
Vernonia galamensis.M.G.Gilbert .var	**	**
Amaranthus spinosus L.	*	*
Euphorbia hirta .L.	*	**
Cuscuta compestris Yuncker	*	-
Sedges		
Cyperus rotundus L.	**	**
Cyperus diformis L.	***	***
Cyperus iria L.	**	***
Cyperus esculentus L.	**	***

* = low infestation

** = moderate infestation

*** = high infestation.

Table 4: List of Common Weed Species and their Level of Infestation in 2011 and 2012 Wet Seasons at Afaka.

Grasses	**2011**	**2012**
Panicum maximum Jacq	**	**
Panicum repens L.	**	**
Imperata cylinderica L.	***	***
Cynodon dactylon L.	**	***
Digitaria horizontalis willd	**	**
Dactyloctenium aegyptium (L.) P.Beauv	**	**
*Sida cardifolia*L.	**	*
Marcus longibracteatu.M.	*	*
Vossia cupidate (Roxb)	*	*
Fimbristylis fereuginea	*	*
Fimbristylis solicifollium L.	*	**
Sacciolepsis africana Hibbs snow dew	**	**
Rottboelia cochinchinensis (Lour) (clayton)	**	***
Paspalum scrobiculatun	*	*
Heteropogon contortus Reom and Schult	*	*
Broad-leaves weed		
Celosia isertii	*	*
Amaranthus spinosus L.	*	*
Ageratum conyzoides L.	***	**
Sida cardifolia L.	**	*
Commelina benghalensis L.	***	***
*Sennabtu sifoli*a L.	***	**
Chromolaena odorata L.	***	***
Heterotis rotundifolia (sm) Jac. Fel	**	**
Ludwigia abysinica A. Rich	**	*
Cuscuta compestris Yuncker	***	-
Sedges		
Cyperus rotundus L.	***	***
Cyperus esculentus L. combestris	***	***
Cyperus iria L.	***	***

* = low infestation

** = moderate infestation

*** = high infestation.

Among broad-leaves species in 2011, *Ageratum conyzoides*, *Cuscuta compestris, Commelina benghalensis*, *Senabtu sifolia* and *Chromolaena odorata* were broad-leaves species with high level of infestation, while in 2012, *Commelina benghalensis* and *Chromolaena odorata* were broad-leaves species with high level of infestation. In 2011 and 2012 at Samaru, *Cyperus esculentus*, and *Cyperus iria* were sedges with high level of infestation, while in Afaka, *Cyperus rotundus, Cyperus esculentus and Cyperus iria*were the sedges with high level of infestation.

4.3. Effects of Weed Control Methods on Weeds

4.3.1 Weed cover score.

The effects of weed control methods on weed cover score at 3, 6, 9 and 12 WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 5 and 6. At Samaru in 2011(Table 5), all the hoe-weeded treatments resulted in significantly lower weed cover score than the weedy check at all sampling periods. Weed cover score by the herbicide treatments were significantly lower than the weedy check, except at 3WAS when only diuron at 2.5 kg a.i /ha gave lower score than the weedy check. In this location, diuron at 2.5 kg a.i /ha resulted in comparable weed cover score reduction to all the other treatments and all the hoe-weedings at 3 and 6WAS. The two and three hoe-weedings gave lower weed cover score than all the other herbicide treatments at 9 and 12WAS. Among the herbicide treatments evaluated, diuron at 2.5 kg a.i /ha resulted in significantly lower weed cover score than all the other herbicide at 12WAS and was comparable only to diuron at 2.0 kg a.i /ha at 9WAS. In Afaka at 3 and 6 WAS in 2011, each herbicide and hoe-weeding treatment resulted in similar and significantly lower weed cover than the weedy check. At 9 and 12WAS, diuron at both rates gave significantly lower weed cover score than all the

Table 5: Effects of Weed Control Methods on Weed Cover Score of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Weed cover score*							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	2.00ab	2.67bc	4.67bc	7.33bc	1.00b	2.00b	4.33b	4.67bc
Oxadiazon	2.0	2.00ab	2.67bc	4.33bc	7.00c	1.00b	2.00b	4.00bc	4.33bc
Diuron	2.0	2.00ab	2.67bc	3.33d	7.33bc	1.00b	2.00b	2.33ef	3.00def
Diuron	2.5	1.67b	2.33cd	3.00d	6.33d	1.00b	2.00b	2.33ef	2.67ef
Metolachlor	1.5	2.33ab	3.00b	5.00bc	7.00c	1.00b	2.33b	3.33cd	4.33bc
Metolachlor	2.0	2.33ab	2.00d	5.09bc	7.67b	1.00b	2.33b	3.67bcd	4.00bc
Butachlor	1.5	2.00ab	3.00b	5.00bc	7.67b	1.00b	2.33b	3.67bcd	4.67bc
Butachlor	2.0	2.00ab	2.67bc	4.67bc	7.67b	1.00b	2.33b	3.00de	4.67bc
Pendimethalin	1.5	2.33ab	2.67bc	4.33bc	7.00c	1.00b	2.33b	3.67bcd	4.67bc
Pendimethalin	2.0	2.33ab	2.00d	4.00c	7.00c	1.00b	2.33b	3.67bcd	3.67cde
HW @ 4WAS	-	1.67b	2.00d	5.67b	7.67b	1.00b	1.00c	4.00bc	5.00b
HW @ 3&6WAS	-	1.67b	2.00d	1.33e	3.67e	1.00b	1.00c	1.67fg	2.33f
HW@3 ,6&9WAS	-	1.67b	2.00d	1.00e	1.00f	1.00b	1.00c	1.33g	1.00g
Weedy check	-	2.67a	6.00a	8.00a	8.67a	2.00a	4.00a	6.67a	7.00a
SE±	-	0.156	0.111	0.264	0.178	0.162	0.128	0.169	0.202

WAS: Weeks after sowing.

*Weed cover score using a scale 1- 9 where 1 represented no weed cover and 9 complete weed cover.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT

other herbicide treatments, but was higher than two and three hoe-weedings which gave the least among the weed control treatments.

In 2012 at Samaru, (Table 6) all herbicide and hoe- weeded treatments significantly reduced weed cover score compared to the weedy check at all sampling periods. At 3WAS, all herbicide treatments resulted in significantly lower weed cover than hoe-weedings and the weedy check.The two and three hoe-weedings gave lower weed cover score than all the other herbicide treatments at 6 and 9WAS. At 12WAS, diuron at 2.5 kg a.i /ha gave significantly lower weed cover than all the other herbicide treatments but was comparable with two hoe-weedings.Three hoe-weedings, at 3, 6 and 9WAS gave significantly lower weed cover compared to all the other weed control treatments.

In 2012 at Afaka, all weed control treatments resulted in significantly lower weed cover score than the weedy check. At 3WAS, diuron at 2.0 kg a.i /ha gave significantly higher weed cover score than the other herbicide and hoe-weeded treatments, while at 6WAS, all herbicide treatments and hoe- weeded control were similar and gave significantly lower weed cover than the weedy check.The hoe-weedings treatments resulted in significantly lower weed cover score than all herbicide treatments that responded differentially at 9WAS. At 12WAS, diuron at 2.5 kg a.i /ha and all the rates of metolachlor, butachlor and pendimethalin gave significantly lower weed cover than all the other herbicide treaments but higher than three hoe-weedings which gave the least among weed control treatments.

4. 3. 2 Weed dry weight (g)

Tables 7 and 8 present effects of weed control methods on weed dry weight at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru

Table 6: Effects of Weed Control Methods on Weed Cover Sore of Roselle during Wet Season of 2012, at Samaru and Afaka

		Weed cover score*							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	1.33c	4.67b	5.33b	5.67c	1.00c	2.67b	3.67b	3.67c
Oxadiazon	2.0	1.67bc	4.33b	5.00b	5.33c	1.00c	2.00b	3.33b	3.67c
Diuron	2.0	1.33c	4.33b	5.33b	5 .67c	1.33b	2.67b	3.00c	3.67c
Diuron	2.5	1.00c	4.00b	5.33b	4.67d	1.00c	2.00b	3.00c	3.33d
Metolachlor	1.5	1.33c	4.67b	5.33b	6.00b	1.00c	2.33b	3.33b	3.33d
Metolachlor	2.0	1.33c	4.33b	5.67b	6.33b	1.00c	2.00b	3.67b	3.00d
Butachlor	1.5	1.33c	4.00b	4.67c	5.67c	1.00c	2.00b	3.00c	3.33d
Butalchlor	2.0	1.33c	4.00b	5.67b	6.33b	1.00c	2.00b	3.00c	3.33d
Pendimethalin	1.5	1.33c	4.00b	5.67b	5.33c	1.00c	2.00b	3.33b	3.33d
Pendimethalin	2.0	1.33c	4.33b	4.00c	5.33c	1.00c	2.00b	3.00c	3.00d
HW @ 4WAS	-	2.00b	2.67c	3.33cd	5.33c	1.00c	1.00b	2.00d	6.00b
HW @ 3&6WAS	-	2.00b	2.67c	3.00d	4.67d	1.00c	1.00b	1.00e	4.33c
HW @3,6&9WAS	-	2.00b	2.67c	3.00d	1.67e	1.00c	1.00b	1.00e	1.67e
Weedy check	-	3.33a	6.67a	8.67a	9.33a	2.00a	4.67a	5.67a	8.67a
SE±		0.158	0.556	0.262	0.159	0.051	0.353	0.213	0.270

WAS: Weeks after sowing.

*Weed cover score using a scale 1- 9 where 1 represented no weed cover and 9 complete weed cover.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT

and Afaka. At Samaru in 2011(Table 7), all herbicides and hoe-weeding treatments resulted in significantly lower weed dry weight than the weedy check at all sampling periods. At 3 and 6WAS diuron at 2.5 kg a.i /ha resulted in significantly lower weed dry weight WDW than all other treatments, but was similar to the two and three hoe-weeded controls at 6WAS. The two and three hoe-weedings resulted in significantly lower weed dry weight (WDW) than the herbicide treatments at 9WAS, while at 12WAS three hoe-weedings gave lower WDW than all the other treatments. Among the herbicide treatments, diuron at 2.5 kg a.i /ha resulted in significantly lower WDW at 9WAS but was at *par* at both rates of oxadiazon and 2.0 kg a.i /ha of diuron at 12WAS.

At Afaka andat 3WAS, all herbicide treatments resulted in significantly lower WDW than hoe-weeding, which in turn was lower at 6WAS. Treatment with diuron at 2.5 kg a.i /ha gave significantly lower WDW than the other herbicide treatments but was significantly higher than by two and three hoe-weedings at 9WAS. At 12WAS, the three hoe-weedings at 3,6 and 9WAS resulted in significantly lower WDW compared to all the other weed control treatments. Among the herbicides, oxadiazon at 2.0 kg a.i /ha and diuron at 2.5 kg a.i /ha gave comparable but lower WDW than the other herbicide treatments.

In 2012 at Samaru (Table 8), all the treatments resulted in similar and significantly lower WDW than the weedy check. At 3WAS, all the treatment resulted in similar WDW and each was lower than by the weedy check. At 6WAS, diuron at 2.5 kg a.i /ha resulted in significantly lower WDW than all other treatments, except hoe-weeding at 4WAS while at 9 and 12WAS diuron at 2.5 kg a.i /ha resulted in significantly lower WDW than the other herbicide treatments, though higher than two and three hoe-weedings.The three hoe-weedings gave significantly lower WDW among the treatments.

Table 7: Effects of Weed Control Methods on Weed Dry Weight (g) of Roselle during Wet Season of 2011, at Samaru and Afaka

		Weed dry weight(g)							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	4.19j	20.22g	35.10e	68.37f	3.00e	11.48d	29.03d	35.03h
Oxadiazon	2.0	4.16k	16.07i	33.07g	64.67g	3.00e	11.23e	18.03g	33.07i
Diuron	2.0	4.19j	19.17h	34.03f	65.67g	3.00e	11.20e	17.87g	36.07g
Diuron	2.5	4.09l	15.07j	32.07h	64.67g	3.00e	11.12e	16.03h	33.00i
Metolachlor	1.5	4.81e	25.96d	38.03d	70.67cd	3.34d	13.26bc	29.07d	45.07d
Metolachlor	2.0	4.41h	24.03e	34.98e	68.67ef	3.00e	13.13c	27.07f	44.10e
Butachlor	1.5	4.95d	28.03b	39.89c	71.33c	3.41c	13.38b	30.07c	46.07c
Butachlor	2.0	4.51g	26.07c	38.03d	70.00d	3.00e	13.17c	28.00e	44.07e
Pendimethalin	1.5	4.71f	24.07e	38.10d	69.67de	3.34d	13.25bc	29.07d	43.00f
Pendimethalin	2.0	4.31i	23.07f	34.03f	62.33h	3.03e	13.11c	27.07f	43.00f
HW @ 4WAS	-	6.11bc	12.07k	98.10b	152.33b	4.00b	3.11g	36.07b	72.07b
HW@3&6WAS	-	6.12b	15.07j	6.12i	42.33i	4.00b	4.03f	7.21i	23.10j
HW@3,6,&9WAS	-	6.10c	15.07j	6.12i	6.16j	4.00b	4.00f	4.07j	6.00k
Weedy check	-	14.96a	96.85a	186.65a	240.66a	4.40a	20.00a	60.00a	83.19a
SE±	-	0.004	0.018	0.025	0.006	0.008	0.031	0.016	0.021

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

At Afaka and at 3WAS in this season, all herbicides treatments resulted in similar and significantly lower WDW than hoe-weeding and weedy check which were similar. At 6 WAS, diuron at the two given rates, resulted in comparable but significantly lower WDW than other herbicide treatments, though higher than the hoe-weeded controls. At 9 and 12WAS, three hoe-weedings gave significantly lower WDW than all the other weed control treatments. Among herbicide treatments, diuron at 2.5 kg a.i /ha gave lower WDW than all other herbicides treatments rates at 12WAS.

4. 3.3 Weed control index

Tables 9 and 10 show the effects of weed control methods on weed control index at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011 at Samaru (Table 9), at 3WAS, diuron at 2.5 kg a.i /ha gave significantly higher WCI than all the other treatments, while at 6WAS; one hoe-weeding gave significantly higher WCI than all the other treatments. At 9 and 12WAS, three hoe-weedings gave significantly highest WCI among weed control treatments. Among the herbicides treatments diuron at 2.5 kg a.i /ha recorded higher WCI compared with other herbicides but at *par* with oxadiazon and pendimethalin each at 2.0 kg a.i /ha and also diuron at 2.0 kg a.i ha at 12WAS.

On the other hand in this year at Afaka, all the herbicide treatments resulted in significantly higher WCI than the weedy check and hoe-weeding treatments at 3WAS. At 6WAS, one hoe-weeding gave significantly higher WCI than all the other treatments, while at 9 and 12 WAS, three hoe-weedings gave significantly higher WCI than all the other weed control treatments. The treatment with diuron at 2.5 kg a.i /ha at 9 and 12WAS gave significantly higher WCI among all other herbicide treatments.

Table 8: Effects of Weed Control Methods on Weed Dry Weight (g) of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Weed dry Weight (g)							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	4.22b	22.20d	37.03d	60.67h	3.67b	13.32b	30.55c	50.01c
Oxadiazon	2.0	4.19b	18.31f	36.07e	54.37j	3.00d	13.26b	30.21d	47.07e
Diuron	2.0	4.41b	14.21g	36.07e	57.70i	3.00d	13.14c	29.23e	46.03f
Diuron	2.5	4.21b	10.11h	36.00e	54.33j	3.00d	13.10c	29.23e	45.07g
Metolachlor	1.5	4.41b	25.07b	40.03c	73 67e	3.24cd	13.37b	28.29f	48.03d
Metolachlor	2.0	4.31b	22.00d	37.09d	71.67g	3.00d	13.25b	28.00g	46.07f
Butachlor	1.5	4.32b	24.00c	40.05c	77.67c	3.34c	13.47b	29.17e	47.03e
Butachlor	2.0	4.21b	22.00d	37.00d	75.67d	3.00d	13.24c	29.00e	46.07f
Pendimethalin	1.5	4.21b	24.03c	40.03c	72.67ef	3.24cd	13.21c	28.41f	48.03d
Pendimethalin	2.0	4.11b	22.10d	37.03d	70.67g	3.00d	13.11c	27.22h	46.00f
HW@ 4WAS	-	5.11b	14.03h	100.10b	129.30b	4.00a	3.00e	34.22b	62.07b
HW@ 3&6WAS	-	5.10b	19.07e	23.10f	48.67k	4.00a	4.00d	10.74i	20.03h
HW @ 3,6&9WAS	-	5.10b	19.07e	20.13g	14.67l	4.00a	4.00d	6.00j	4.07i
Weedy check	-	11.34a	99.93a	220.42a	270.75a	4.26a	20.20a	60.51a	80.44a
SE$\pm$	-	0.851	0.050	0.023	0.172	0.051	0.081	0.051	0.018

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 9: Effects of Weed Control Methods on Weed Control Index of Roselleduring Wet Season of 2011, at Samaru and Afaka.

		Weed control index							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	72.00b	79.12e	81.20e	71.59ef	31.82a	42.60d	51.62g	57.89d
Oxadiazon	2.0	72.19b	83.41c	82.28c	73.14cd	31.82a	43.85c	69.95d	60.25c
Diuron	2.0	71.99b	80.26d	81.77d	72.71d	31.82a	44.00c	70.22d	56.64d
Diuron	2.5	72.66a	84.44b	82.82b	73.13cd	31.82a	44.40c	73.28c	60.33c
Metolachlor	1.5	67.85f	73.20h	79.63f	70.64f	24.09b	33.70ef	51.55g	45.83ef
Metolachlor	2.0	70.52d	75.19g	81.26e	71.47ef	31.82a	34.35e	55.00e	47.99e
Butachlor	1.5	66.91g	71.05i	78.63g	70.36f	22.50c	33.10f	49.88h	44.62f
Butachlor	2.0	69.52e	73.08h	79.63f	70.91f	31.14a	34.15e	53.33f	47.02e
Pendimethalin	1.5	68.52e	75.15g	79.64f	71.05f	24.09b	33.75ef	51.55g	48.31e
Pendimethalin	2.0	71.19c	76.18f	81.77d	74.10c	31.14a	34.45e	54.88e	48.31e
Hw @ 4weeks	-	59.16h	87.54a	47.44h	36.70g	9.09d	84.45a	39.88i	13.37g
Hw @ 3&6WAS	-	59.09h	84.44b	96.72a	82.41b	9.09d	79.85b	87.98b	72.23b
Hw @ 3,6,9WAS	-	59.23h	84.44b	96.72a	97.44a	9.09d	80.00b	93.22a	92.89a
Weedy check	-	0.00i	0.00j	0.00i	0.00h	0.00e	0.00g	0.00j	0.00h
SE±	-	0.032	0.048	0.013	0.245	0.033	0.144	0.146	0.642

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

In 2012 at Samaru (Table 10) and at 3WAS, treatment with pendimethalin at 2.0 kg a.i /ha gave significantly higher WCI than all the other treatments that responded differentially in WCI at 3WAS. At 6WAS, diuron at 2.5 kg a.i /ha gave significantly higher WCI than all the other treatments which also responded differently.The three hoe-weedings gave significantly higher WCI than all the other treatments at 9 and 12 WAS. Weed control index by the herbicide treatment were statistically at *par* at 9WAS, but diuron at 2.5 kg a.i /ha and oxadiazon at 2.0 kg a.i /ha had similar and higher WCI than the other herbicide treatment and one hoe-weeding when sampled at 12WAS.

In 2012 at Afaka and at 3WAS, all the herbicide treatments resulted in significantly higher WCI than hoe-weeding irrespective of frequency, but the reverse was the case at 6WAS. At 9 and 12WAS, three hoe-weedings gave significantly higher WCI than all the other weed control treatments. Among the herbicides; diuron at 2.5 kg a.i /ha recorded higher WCI at 12WAS but was at *par* with 2.0 kg a.i /ha at 9WAS.The least WCI was consistently obtained from weedy check.

4.3.4 Herbicide efficiency index.

The response of herbicide efficiency index at 12WAS of roselle during wet seasons of 2011 and 2012 is presented in Table 11. In Samaru 2011 and 2012, pendimethalin at 2.0 kg a.i /ha resulted in significantly higher herbicide efficiency index than its all other herbicide treatments. The least index was obtained by butachlor at 1.5 kg a.i /ha but was at *par* with butachlor at 2.0 kg a.i ha; metolachlor at 1.5 kg a.i ha; diuron at 2.5 kg a.i ha and oxadiazon at 2.0 kg a.i ha in 2011, the value of which was lower than by the other herbicide treatments.

Similarly in 2011and 2012 at Afaka, metolachlor at 1.5 kg a.i /ha and pendimethalin at the two given rates gave significantly higher herbicide efficiency index, which was only

Table 10: Effects of Weed Control Methods on Weed Control Index of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Weed control index							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3 WAS	6 WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	62.79c	77.78d	83.20b	77.59e	13.85d	34.06f	49.51g	37.83g
Oxadiazon	2.0	63.05b	81.68c	83.64b	79.92c	29.58a	34.36e	50.07g	41.48e
Diuron	2.0	61.11e	85.78b	83.64b	78.69d	29.58a	34.95d	55.00c	42.78d
Diuron	2.5	62.87bc	89.88a	83.67b	79.93c	29.58a	35.15c	55.00c	43.97c
Metachlor	1.5	61.11e	74.98e	81.84b	72.79f	23.94b	33.82f	53.23e	40.29f
Metachlor	2.0	61.99d	77.99d	83.17b	73.53e	29.58a	34.41e	53.73d	42.73d
Butachlor	1.5	61.91d	75.98de	81.83b	71.31g	22.54c	33.32g	51.78f	41.56e
Butachlor	2.0	62.87bc	77.98d	83.21b	72.05f	29.58a	34.46e	52.07f	42.73d
Pendimethalin	1.5	62.87bc	75.32e	81.84b	73.16e	23.94b	34.60d	53.05e	40.29f
Pendimethalin	2.0	63.76a	77.89d	83.20b	73.90e	29.58a	35.10c	55.01c	42.84d
HW @ 4 WAS	-	54.94f	85.96b	54.58c	52.24h	6.10e	85.15a	43.45h	22.84h
HW @ 3&6 WAS	-	55.02f	80.92c	89.52a	82.02b	6.10e	80.20b	82.23b	75.10b
HW @3,6&9WAS	-	55.02f	80.92c	90.87a	94.58a	6.10e	80.20b	90.08a	94.94a
Weedy check	-	0.00g	0.00f	0.00d	0.00i	0.00e	0.00h	0.00i	0.00i
SE+	-	0.063	0.619	0.835	0.063	0.030	0.053	0.085	0.023

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 11: Effects of Weed Control Methods on Herbicide Efficiency Index of Roselle during Wet Seasons of 2011 and 2012, at 12WAS at Samaru and Afaka.

		Herbicide efficiency index			
		Samaru		Afaka	
Treatment	Rates(kg a.i/ha)	2011	2012	2011	2012
Oxadiazon	1.5	185.81d	203.71c	63.97c	53.90c
Oxadiazon	2.0	189.88bcd	211.69b	51.27d	44.54d
Diuron	2.0	185.91d	205.18c	0.10e	40.66d
Diuron	2.5	186.25cd	209.10b	0.10e	40.67d
Metolachlor	1.5	187.68bcd	204.76c	75.27ab	65.24a
Metolachlor	2.0	192.51b	200.53d	68.11b	61.31ab
Butachlor	1.5	185.00d	190.73e	63.47c	56.58bc
Butachlor	2.0	187.57bcd	198.48d	63.86c	51.49c
Pendimethalin	1.5	191.96bc	209.97b	82.80a	64.67a
Pendimethalin	2.0	212.63a	219.50a	82.81a	64.92a
Hw @ 4WAS	-	NA	NA	NA	NA
Hw @ 3&6WAS	-	NA	NA	NA	NA
Hw@ 3,6,&9WAS	-	NA	NA	NA	NA
Weedy Check	-	NA	NA	NA	NA
SE$\pm$		1.028	1.048	1.983	1.072

Means followed by the same letter(s) within a column of each set of treatment group are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

NA: Not Applicable: because plots did not receive any herbicides application.

comparable to metolachlor at 1.5 kg a.i /ha in 2011 and 2.0 kg a.i /ha in 2012. The least values were obtained by diuron at both rates and seasons.

4.4 Crop Establishment and Growth Characters

4.4.1 Percentage seedling emergence.

Table 12 shows the effects of weed control methods on percentage seedling emergence of roselle at 2WAS during wet seasons of 2011 and 2012 and combined mean at Samaru and Afaka. In 2011 and the combined data at Samaru, treatments with oxadiazon at 1.5 to 2.0 kg a.i /ha and diuron at 2.0 to 2.5 kg a.i /ha resulted in lower percentage seedling emergence than all the other treatments. This character was not affected by weed control treatment in 2012. Similarly, oxadiazon and diuron each at the two given rates reduced crop seedling emergence over all other treatments which gave similar result in both years and the combined data at Afaka.

4.4.2 Crop injury

The effects of weed control methods on crop injury score at 2WAS of roselle during wet seasons of 2011 and 2012 at Samaru sand Afaka is shown in Table 13. In 2011 at Samaru, the two rates, each of oxadiazon and diuron were phytotoxic to roselle compared to all the other herbicides treatments, all of which were safe on the crop except oxadiazon at 1.5 kg a.i ha which was moderately toxic. In 2012, all treatments were safe and similar in the injury score.

However, in 2011 at Afaka, diuron at both rates was phytotoxic to the crop than all the other treatments, except oxadiazon at 1.5 kg a.i/ha. Butachlor at 1.5 kg a.i /ha was least toxic and comparable to the weeded controls. In 2012 oxadiazon at 2.0 kg a.i/ ha scored higher toxicity than all the other treatments except its 1.5 kg a.i/ha rate, which was similar to diuron at 2.5 kg a.i/ha, all of which were more toxic than the remaining treatments.

Table 12: Effects of Weed Control Methods on Percentage Seedling Emergence of Roselle during Wet Seasons of 2011, 2012 and Combined at 2WAS at Samaru and Afaka.

		Percentage seedling emergence					
		Samaru			Afaka		
Treatment	Rates (kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	43.37b	91.10	67.24b	27.77b	50.03b	38.90b
Oxadiazon	2.0	28.70c	92.53	60.62c	34.26b	42.27b	38.27b
Diuron	2.0	19.43d	99.07	59.25c	0.10c	91.67a	45.88b
Diuron	2.5	15.73d	94.40	55.07c	0.10c	21.40c	10.70c
Metolachlor	1.5	97.27a	98.13	95.47a	91.67a	88.90a	90.28a
Metolachlor	2.0	90.73a	97.20	94.90a	87.04a	91.67a	89.34a
Butachlor	1.5	88.83a	99.07	93.95a	97.22a	88.87a	93.05a
Butachlor	2.0	90.43a	97.20	95.22a	91.67a	90.73a	91.20a
Pendimethalin	1.5	97.20a	100.00	97 67a	88.89a	100.00a	94.45a
Pendimethalin	2.0	92.57a	98.13	95.35a	96.29a	96.27a	96.28a
Hw @ 4WAS	-	96.27a	98.13	97.20a	95.37a	97.20a	96.29a
Hw @ 3&6WAS	-	96.27a	98.13	97.20a	97.22a	99.07a	98.15a
Hw @ 3,6,&9WAS	-	96.70a	98.13	97.20a	98.15a	98.13a	98.15a
Weedy check	-	92.53a	97.20	94.87a	94.44a	99.07a	96.77a
SE±		1.805	1.756	1.781	2.754	3.534	2.644

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

Table 13: Effects of Weed Control Methods on Crop Injury of Roselle during Wet Seasons of 2011 and 2012, at 2WAS at Samaru and Afaka.

		Crop injury *			
		Samaru		Afaka	
Treatment	Rates (kg a.i/ha)	2011	2012	2011	2012
Oxadiazon	1.5	6.67b	2.00	8.00ab	6.33ab
Oxadiazon	2.0	7.67a	2.33	7.33b	8.00a
Diuron	2.0	8.00a	1.33	9.00a	2.33c
Diuron	2.5	8.00a	2.00	9.00a	6.00b
Metolachlor	1.5	1.67c	1.67	2.67c	2.33c
Metolachlor	2.0	2.33c	1.33	2.00c	2.00c
Butachlor	1.5	2.67c	1.33	1.67d	2.33c
Butachlor	2.0	2.33c	1.33	2.00c	2.67c
Pendimethalin	1.5	1.67c	1.00	2.67c	1.00c
Pendimethalin	2.0	2.00c	1.67	2.00c	2.00c
Hw @ 4WAS	-	1.67c	1.33	1.67d	1.67c
Hw @ 3&6WAS	-	1.67c	1.67	1.67d	1.33c
Hw @3,6,&9WAS	-	2.33c	1.33	1.33d	1.33c
Weedy check	-	2.33c	1.67	2.00c	1.33c
SE$\pm$		0.230	0.241	0.279	0.341

*Crop injury score using a scale 1- 9 where 1 represented the least injured plants and 9 the most injured plants.
Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

4.4.3 Percentage stand count at harvest

Table 14 shows the effects of weed control methods on percentage stand count at harvest of roselle during wet seasons of 2011 and 2012 at Samanru and Afaka. In 2011 at Samaru, treatment with metolachlor at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i /ha gave significantly higher percentage stand at harvest than all the other treatments. Diuron at two given rates gave the least among the treatment. At Afaka, each treatment resulted in similar and significantly higher percentage stand count at harvest including the weedy check.

In 2012 at Samaru, butachlor, metolachlor and pendimethalin each at the two given rates and oxadiazon at 1.5 kg a.i /ha resulted in similar and significantly higher stand count at harvest compared to other treatments, including the weedy check. The least stand count was obtained by diuron at 2.5 kg a.i /ha. At Afaka, all treatments resulted in higher stand count at harvest including the weedy check, compared to diuron at both rates and oxadiazon at the two available rates in 2011. Treatment with oxadiazon at 2.0 kg a.i /ha gave the least among the treatments.

4.4.4 Crop vigor score.

Tables 15 and 16 present the effects of weed control methods on crop vigor score of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka. At 3 and 6WAS in 2011 at Samaru (Table 14), crop vigour score was depressed by oxadiazon at 1.5-2.0 kg a.i /ha and diuron at 2.0-2.5 kg a.i /ha compared to all the other treatments, except metolachlor at 2.0 kg a.i /ha and the weedy check at 6WAS. Metolachlor at 1.5 kg a.i/ha, pendimethalin at the two given rates were comparable to hoe-weeded treatment at 3 and 6WAS when sampled at 3WAS. At 6WAS, metolachlor at 1.5 kg a.i/ha and hoe-weedings at 3 and 6 WAS

Table 14: Effects of Weed Control Methods on PercentageStand Count at Harvest of Roselle during Wet Seasons of 2011 and 2012, at Samaru and Afaka.

		% Stand count at harvest			
		Samaru		Afaka	
Treatment	Rates (kg a.i/ha)	2011	2012	2011	2012
Oxadiazon	1.5	43.53e	99.08a	29.67b	50.00e
Oxadiazon	2.0	28.69f	88.89c	34.25b	21.31f
Diuron	2.0	19.44g	95.36b	0.10c	92.58a
Diuron	2.5	15.75h	84.25d	0.10c	45.36ef
Metolachlor	1.5	97.22a	99.08a	92.58a	87.03bc
Metolachlor	2.0	90.75bc	99.08a	87.02a	84.25c
Butachlor	1.5	89.81c	98.53a	97.22a	84.25c
Butachlor	2.0	85.19d	99.08a	97.22a	76.86d
Pendimethalin	1.5	88.89c	99.08a	91.67a	94.44a
Pendimethalin	2.0	95.36a	99.08a	88.89b	90.75b
HW @ 4WAS	-	90.75bc	96.31b	94.44a	96.31a
HW @ 3&6WAS	-	90.75bc	89.81c	97.22a	92.58a
HW @ 3,6& 9WAS	-	84.25d	85.19d	89.81b	91.67a
Weedy check	-	92.58bc	98.14ab	89.81b	87.03b
SE±		0.659	0.159	0.990	1.288

Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

gave more vigorous crop than treatments with oxadiazon and diuron each at two given rates, metolachlor at 2.0 kg a.i /ha and weedy check but were comparable to the rest of the remaining treatments. At 9 and12WAS in this location, crop vigour by two and three hoe - weedings and pendimethalin at two given rates at 12WAS were similar, and each was greater than both treatments rates of oxadiazon and diuron and single hoe-weeding at 4WAS and the weedy check.The two treatments, each of oxadiazon and diuron gave lower crop vigour than all the other, except pendimethalin at 2.0 kg a.i /ha, hoe-weeding at 4WAS and the weedy check.

At Afaka in 2011, the weedy check and the three hoe-weeded controls gave higher crop vigour than all the other treatments, except butachlor at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i /ha when sampled at 3WAS. At 6WAS, the three hoe-weeded controls gave similar and greater crop vigour than all the other treatments, followed by the treatments with metolachlor, butachlor and pendimethalin, each of which gave more vigorous crop than the rest including the weedy check. At 9WAS, pendimethalin at 2.0 kg a.i /ha and three hoe-weedings gave higher crop vigour score than all the other treatments, except pendimethalin and metolachlor each at 1.5 kg a.i /ha and two hoe-weedings at 3and 6WAS. At 12WAS, pendimethalin at both rates, metolachlor at 1.5 kg a.i /ha and three hoe-weeding at 3, 6 and 9 WAS gave similar and greater crop vigour than by all the other treatments, except metolachlor at 2.0 kg a.i /ha, butachlor at 1.5 and 2.0 kg a.i /ha and two hoe-weedings at 3and 6WAS. Treatments with diuron consistently gave the least crop vigour.

In 2012 at both locations (Table 16), there was change in the trend of results. At 3WAS in Samaru, one hoe weeding at 4WAS gave greater crop vigour score than the other treatments in the trial, except pendimethalin at 1.5 kg a.i /ha and two hoe- weedings at 3 and 6WAS, which in turn were higher than the rest of the treatments. At 6WAS, two and three hoe-weedings gave more vigorous crop than all the other treatment, except one hoe-weeding at 4WAS. At 9WAS, two and three hoe-weedings at 3and 6 WAS and 3, 6 and 9WAS, oxadiazon and butachlor, each at 1.5 kg a.i /ha resulted in higher crop vigour score than the weedy check, oxadiazon and diuron, each at 2.0 kg a.i /ha and metolachlor at 1.5 kg a.i /ha. At 12WAS, butachlor at 1.5 kg a.i /ha gave higher crop vigour score than all the other treatments, except oxadiazon at 1.5 kg a.i /ha, pendimethalin at 1.5 and 2.0 kg a.i /ha and the three hoe-weeded control, each of which was in turn higher than one and two hoe-weedings and oxadiazon, diuron and butachlor each at 2.0 kg a.i /ha.The weedy check consistently gave the least vigorous crop in this trial.

In 2012 at Afaka, three hoe-weeded controls and the two rates of pendimethalin resulted in higher crop vigour than the weedy check when sampled at 3WAS. At 6WAS, one and two hoe-weedings gave more vigorous crop than the other treatments, except treatments with metolachlor and butachlor, each at the two available rates and pendimethalin at 2.0 kg a.i /ha which in turn higher than treatments with oxadiazon and diuron, as well as the weedy check. At 9WAS, the greatest crop vigour was by three hoe-weeding at 3, 6 and 9WAS, and this was higher than by all the other treatments. Followed by pendimethalin at 2.0 kg a.i /ha, which in turn higher than the rest. At 12WAS, the best crop vigour was by three hoe-weedings and butachlor at 1.5 kg a.i /ha, which gave higher crop vigour than by all the other treatments, except butachlor at 2.0 kg a.i /ha and pendimethalin at the two given rates, which in turns gave higher than the given rates of oxadiazon and diuron, metolachlor at 2.0 kg a.i /ha and the weedy check.

Table 15: Effects of Weed Control Methods on Crop Vigour Score of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Crop vigour score*							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	5.00e	6.00d	7.33cd	7.00cd	6.00c	6.00cd	6.67ef	7.33c
Oxadiazon	2.0	4.00f	6.33cd	7.00d	7.67bc	6.33c	6.33c	7.33de	7.67bc
Diuron	2.0	4.00f	4.33e	6.00e	6.33de	0.10d	0.10e	0.10h	0.10e
Diuron	2.5	3.67f	4.00e	5.00f	5.67e	0.10d	0.10e	0.10h	0.10e
Metolachlor	1.5	8.67ab	9.00a	8.33abc	8.67a	8.00b	8.00b	8.33abc	8.67a
Metolachlor	2.0	7.33cd	7.33bc	8.00a-d	8.33ab	8.00b	8.00b	8.00bcd	8.33ab
Butachlor	1.5	7.00d	8.00ab	8.00a-d	8.33ab	8.67ab	8.00b	8.00bcd	8.33ab
Butachlor	2.0	7.33cd	8.00ab	7.67bcd	8.33ab	8.00b	7.67b	7.67cd	8.33ab
Pendimethalin	1.5	9.00a	8.00ab	8.67ab	9.00a	8.00b	7.67b	8.67ab	9.00a
Pendimethalin	2.0	8.33ab	8.67ab	8.33abc	9.00a	8.33ab	8.00b	9.00a	9.00a
HW @ 4WAS	-	8.67ab	8.67ab	7.33cd	7.33c	9.00a	8.67a	6.33f	5.67d
Hw @ 3&6WAS	-	9.00a	9.00a	9.00a	9.00a	9.00a	8.67a	8.67ab	8.33ab
Hw @ 3,6, &9WAS	-	8.00bc	8.00ab	9.00a	9.00a	9.00a	9.00a	9.00a	9.00a
Weedy check	-	9.00a	7.33bc	7.00d	6.33de	9.00a	5.67d	5.33g	5.00d
SE±	-	0.131	0.242	0.183	0.158	0.130	0.104	0.172	0.148

* Crop vigour score using a scale of 1- 9 where 1 represented completely death plants and 9 represented most vigorous plants.

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

Table 16: Effects of Weed Control Methods on Crop Vigour Score of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Crop vigour score *							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	4.67fg	7.00def	8.67ab	9.00ab	7.00c	7.67cd	6.00def	7.00e
Oxadiazon	2.0	6.33cd	8.00bc	7.00cd	8.00bc	7.00c	7.67cd	6.00def	7.67cde
Diuron	2.0	6.67cd	6.33g	6.67d	8.00bc	7.00c	7.33d	6.33cde	7.33de
Diuron	2.5	6.00de	6.67efg	7.67a-d	7.67cd	7.00c	7.33d	5.33fg	7.00e
Metolachlor	1.5	6.00de	7.00def	7.33cd	7.00d	8.33b	8.67ab	6.33cde	7.33de
Metolachlor	2.0	5.33ef	7.33cde	8.33abc	7.67cd	8.33b	8.67ab	6.33cde	8.00bcd
Butachlor	1.5	6.67cd	8.00bc	8.67ab	9.33a	8.33b	8.33abc	7.00bc	9.00a
Butachlor	2.0	7.00bc	7.67bcd	8.33abc	8.00bc	8.33b	8.33abc	6.33cde	8.33abc
Pendimethalin	1.5	7.67ab	7.33cde	8.00a-d	9.00ab	9.00ab	8.00bcd	6.67bcd	8.67ab
Pendimethalin	2.0	7.00bc	8.00bc	8.33abc	9.00ab	9.00ab	8.33abc	7.33b	8.33abc
HW @ 4WAS	-	8.00a	8.33ab	8.00a-d	8.67bc	9.00ab	9.00a	5.67efg	5.67f
HW @ 3&6WAS	-	7.67ab	9.00a	8.67ab	8.33bc	9.33a	9.00a	7.00bc	7.33de
HW @ 3,6&9WAS	-	7.00bc	9.00a	9.00a	9.00ab	9.00ab	8.00bcd	8.33a	9.00a
Weedy check	-	4.33g	6.00h	7.00cd	6.00d	7.00c	7.33d	5.00g	5.33f
SE±	-	0.173	0.152	0.273	0.173	0.116	0.159	0.150	0.158

* Crop vigour score using a scale of 1- 9 where 1 represented completely death plants and 9 represented most vigorous plants.

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT

4.4.5 Plant height (cm).

Tables 17 and 18 present the effects of weed control methods on plant height at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011 at Samaru (Table 17), all herbicide and hoe-weeding treatments resulted in significantly taller plants than the weedy check throughout the sampling periods. At 3WAS, two and three hoe-weeded controls at 3 and 6WAS and 3, 6 and 9WAS resulted in similar and taller plants than all the other treatments including the weedy check, except treatment with pendimethalin at 2.0 kg a.i/ha. At 6WAS, treatment with pendimethalin at 2.0 kg a.i/ha resulted in taller plants than all the other treatments, except three hoe-weedings at 3, 6 and 9WAS. At 9WAS, the three hoe-weedings at 3, 6 and 9WAS produced taller plants than all the other treatment, followed by treatments with pendimethalin at 2.0 kg a.i /ha and two hoe-weedings at 3 and 6WAS, each of which gave taller plants than the rest, including the weedy check. At 12WAS, hoe-weedings at 3, 6 and 9WAS gave taller plants than all the other treatments, except treatments with pendimethalin at the two given rates.

At 3WAS in the same year at Afaka, pendimethalin at 2.0 kg a.i /ha resulted in taller plants than all the other treatments including the weedy check, except oxadiazon at 2.0 kg a.i /ha, metolachlor, butachlor and pendimethalin each at 1.5 kg a.i /ha and two and three hoe-weedings. At 6WAS, hoe-weedings at 3, 6 and 9WAS gave taller plants than all the treatments, except two hoe-weedings at 3 and 6WAS. At 9WAS, two hoe-weedings produced taller plants than all the other treatments, except treatments with metolachlor at 1.5 kg a.i /ha, pendimethalin at the two given rates and three hoe-weeding at 3,6 and 9WAS, which in turn gave taller plants than the rest including the weedy check. At 12WAS, treatments with metolachlor at 1.5 and 2.0 kg a.i /ha, pendimethalin at 2.0 kg a.i

Table 17: Effects of Weed Control Methods on Plant Height (cm) of Roselle during Wet Season of 2011, at Samaru and Afaka

		Plant height (cm)							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	40.33abc	44.00ef	58.00e	114.53bc	18.57bcd	38.43de	58.57cd	78.00b
Oxadiazon	2.0	38.33cde	44.33ef	63.00d	105.77bcd	19.87abc	34.53f	52.27e	74.30b
Diuron	2.0	37.50de	41.67fg	58.00e	102.77bcd	0.10e	0.10g	0.10g	0.10d
Diuron	2.5	37.47de	46.33de	61.67d	101.67cd	0.10e	0.10g	0.10g	0.10d
Metolachlor	1.5	37.47de	48.00cd	66.67c	106.43bcd	22.00ab	42.10bcd	66.20ab	94.50a
Metolachlor	2.0	35.67e	48.33a-d	68.33c	109.63bc	18.53bcd	38.23e	62.97bc	94.20a
Butachlor	1.5	38.00cde	45.67de	62.33d	111.50bc	21.23abc	36.70e	62.23bc	78.80b
Butachlor	2.0	37.53de	48.33a-d	62.33d	107.33bc	17.93cd	39.23cde	62.97bc	79.40b
Pendimethalin	1.5	38.53bcd	50.33abc	69.67c	118.46ab	20.13abc	42.40bc	66.37ab	82.00b
Pendimethalin	2.0	41.07ab	52.00a	73.33b	118.73ab	23.00a	42.73bc	64.93ab	95.80a
HW @ 4WAS	-	40.33abc	46.00de	59.67de	91.33d	19.67a-d	43.50b	55.27de	75.10b
HW @ 3&6WAS	-	41.73a	50.00abc	76.67b	113.77bc	20.57abc	44.93ab	69.50a	107.00a
HW@ 3 ,6& 9WAS	-	42.60a	51.67ab	80.33a	132.73a	18.83bcd	48.37a	65.80ab	102.00a
Weedy check	-	32.00f	39.00g	49.67f	76.87e	16.20d	33.50f	42.90f	65.50c
SE±		0.483	0.616	0.669	2.800	0.621	0.695	0.980	4.390

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

/ha, hoe-weeded controls at 3 and 6WAS and 3,6 and 9WAS resulted in similar plants height each /ha, hoe-weeded controls at 3 and 6WAS and 3,6 and 9WAS resulted in similar plants height each of which gave taller plant than by all the other treatments. The treatments with diuron at the two given rates consistently gave shortest plants throughout the sampling periods.

In 2012 at both locations (Table 18), all treatments resulted in taller plants than the weedy check throughout the sampling periods. At Samaru and at 3WAS, treatment with metolachlor at1.5 kg a.i /ha gave taller plants than all the other treatments, followed by pendimethalin at 1.5 and 2.0 kg a.i /ha, each of which gave taller plants than theother treatments. At 6WAS, the treatments with pendimethalin at two given rates resulted insimilar plant height but at *par* with metolachlor at two given rates while at 9WAS, three hoe-weedings at 3, 6 and 9WAS gave significantly taller plants than all the other treatments, except two hoe-weeding at 3 and 6WAS. At 12WAS, pendimethalin at 2.0 kg a.i /ha and hoe-weeding at 3, 6 and 9WAS gave similar plant height, each of which gave greater height than by the other treatments in the trial, except by two hoe-weeding at 3 and 6WAS.

In this year at Afaka, hoe-weeding and herbicide treatments enhanced plant height over the weedy check, except those with pendimethalin at two given rates and oxadiazon at 2.0 kg a.i /ha at when sampled at 3WAS. At 6WAS, three hoe-weedings significantly produced taller plants than all the other treatments, which in turn gave taller plants than the weedy check at various ratings. At 9WAS, metolachlor at 2.0 kg a.i /ha gave taller plants than all the other treatments, except its rates at 1.5 kg a.i /ha. The hoe-weeded and other herbicide treatments resulted in taller plants than the weedy check. At 12WAS, three hoe-weeded

Table 18: Effects of Weed Control Methods on Plant Height (cm) of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Plant height (cm)							
		Samaru				Afaka			
Treatment	Rates (kg ai/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	38.33b-e	49.00e	67.33fg	106.00ef	24.33bcd	54.07cd	70.33bc	95.20cd
Oxadiazon	2.0	38.67b-e	50.00de	69.00def	112.00c-f	22.33e	53.50de	65.47d	95.30cd
Diuron	2.0	36.00e	48.67e	62.00g	104.00f	25.23abc	51.37e	70.37bc	98.27cd
Diuron	2.5	36.67de	50.33de	62.33g	108.67def	25.70ab	53.03de	69.43c	92.93d
Metolachlor	1.5	44.00a	56.67abc	70.00def	127.67bc	24.50bcd	57.73b	73.50ab	99.93bc
Metolachlor	2.0	40.67bc	56.67abc	71.33de	129.67bc	26.50a	56.80b	75.23a	104.67b
Butachlor	1.5	39.00bcd	52.67cd	65.00fg	122.67b-e	25.17abc	54.03cd	67.53cd	97.40cd
Butachlor	2.0	38.00cde	53.33bcd	66.00fg	124.33b-e	24.80abc	53.53de	68.13cd	98.10cd
Pendimethalin	1.5	41.00b	58.00a	74.00cd	133.00b	22.93de	53.50de	69.83bc	104.03b
Pendimethalin	2.0	41.00b	58.00a	77.00bc	153.00a	23.47cde	52.57de	70.83bc	105.00b
HW @ 4 WAS	-	37.00de	50.33de	62.67g	126.67bcd	25.47ab	56.10bc	61.43e	80.63e
HW @ 3 &6WAS	-	38.33b-e	53.33bcd	81.33ab	136.67ab	25.30abc	58.07b	71.03bc	103.87b
HW @ 3,6 &9 WAS	-	39.00bcd	56.00abc	85.67a	151.00a	25.63ab	60.53a	68.67de	121.83a
Weedy check	-	31.00f	38.33f	53.33h	87.00g	21.80e	45.33f	51.43f	69.63f
SE$\pm$	-	0.495	0.690	0.949	3.319	0.334	0.416	0.674	3.322

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

controls gave taller plants than all the other treatments, which in turn had edge over the weedy check.

4.4.6 Number of leaves/plant

The effects of weed control methods on number of leaves/plant at 3, 6, 9 and 12 WAS of roselle during wet seasons of 2011and 2012 at Samaru and Afaka are shown in Tables 19 and 20. In 2011 at Samaru and at 3WAS (Table 19), three hoe-weedings and pendimethalin at 2.0 kg a.i /ha resulted in similar and produced significantly more number of leaves/plant than all the other treatments, except pendimethalin at 1.5 kg a.i /ha and two hoe-weedings at 3and 6WAS. At 6WAS, pendimethalin at 2.0 kg a.i /ha and three hoe-weedings gave similar and more number of leaves/plant than all the other treatments, except one hoe-weeding at 4WAS while at 9WAS, three hoe-weedings at 3, 6and 9WAS produced more number of leaves/plant than all the other treatments. This was followed by pendimethalin at 2.0 kg a.i /ha which in turn gave more number of leaves/plant than the rest of the treatments. At 12WAS, pendimethalin at 2.0 kg a.i /ha and three hoe-weedings resulted in similar and gave more number of leaves/plant than all the other treatments including the weedy check, except pendimethalin at 1.5 kg a.i /ha and metolachlor at 2.0 kg a.i/ha which in turn produced more number of leaves/plant than the remaining treatments.

At Afaka and at 3WAS, three hoe-weedings at 3,6 and 9WAS produced more number of leaves/plant but at *par* with the remaining treatments, except treatment with oxadiazon at 1.5 kg a.i /ha, diuron at two given rates, metolachlor at 1.5 kg a.i /ha and weedy check. At 6WAS, three hoe-weeding at 3,6 and 9WAS resulted in more number of leaves/plant than all the other treatments. This was followed by the two hoe-weeding at 3and 6WAS, which in turn produced more leaves than by all the other treatments. At 9WAS, the two and three

Table 19: Effects of Weed Control Methods on Number of Leaves/plant of roselle during Wet Season of 2011, at Samaru and Afaka

		Number of leaves/plant							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	21.67bcd	31.33ef	68.67bc	85.33d	26.00cd	39.33de	63.33b	73.33e
Oxadiazon	2.0	15.33fg	32.00ef	61.33cd	86.00cd	30.33a-d	40.33de	57.33c	68.67e
Diuron	2.0	17.00efg	20.33g	40.33f	69.00e	0.10e	0.10g	0.10f	0.10f
Diuron	2.5	14.33g	34.33c-f	49.67e	72.00e	0.10e	0.10g	0.10f	0.10f
Metolachlor	1.5	20.00de	33.33def	64.33bc	88.67bcd	27.67bcd	41.00de	56.33c	80.33d
Metolachlor	2.0	20.67cd	33.67c-f	61.67cd	94.00abc	29.33a-d	38.00ef	51.33d	80.67d
Butachlor	1.5	18.67def	36.00b-e	60.00cd	89.00bcd	30. 33a-d	35.67f	58.00c	87.00c
Butachlor	2.0	19.67de	32.00ef	58.33cd	86.33cd	30.00a-d	46.67c	55.33c	89.33cd
Pendimethalin	1.5	25.00ab	38.00a-d	65.00bc	96.00ab	30.67a-d	42.33d	57.33c	96.00b
Pendimethalin	2.0	26.00a	41.33a	71.33b	100.67a	31.67abc	40.00de	62.67b	96.67b
HW @ 4WAS	-	22.00bcd	40.00ab	62.67c	75.33e	31.33abc	42.33d	51.33d	72.00e
HW @ 3&6 WAS	-	23.67abc	38.33abc	66.00bc	93.00a-d	32.67ab	50.00b	74.00a	100.67b
HW @ 3,6&9 WAS	-	26.33a	41.67a	82.67a	100.33a	33.67a	56.00a	75.00a	125.33a
Weedy check	-	16.00fg	30.33f	54.33de	58.33f	26.67cd	41.00de	45.67e	74.00e
SE+		0.654	0.874	1.341	1.444	0.907	0.562	0.701	1.079

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

hoe-weedings gave similar and produced more number of leaves/plant than all the other treatments.This was followed by oxadiazon at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i /ha, each of which gave more number of leaves/plant than the other treatments, including the weedy check. At 12WAS, three hoe-weedings at 3,6 and 9WAS resulted in more number of leaves/plant than all the other treatments.Two hoe-weeding at 3 and 6WAS and pendimethalin at the two given rates gave more number of leaves/plant than the rest of the treatments. Diuron at the two given rates consistently gave the least number of leaves/plant in the trial.

In 2012 at Samaru and at 3WAS (Table 20), pendimethalin at 1.5 kg a.i /ha produced significantlymore number of leaves/plant than all the other treatments, except pendimethalin at two given rates. At 6WAS, three hoe-weedings at 3, 6 and 9WAS gave more number of leaves/plant than all the other treatments, except pendimethalin at 1.5 kg a.i /ha while at 9WAS, three hoe-weedigs at 3, 6and 9WAS produced more number of leaves/plant than all the other treatments, except two hoe-weeding at 3 and 6WAS. At 12WAS, pendimethalin, butachlor, diuron, each at the two given rates and three hoe-weedings at 3, 6 and 9WAS, gave similar and number of leaves/plant than all the other treatments. This was followed by oxadiazon, metolachlor each at the two given rates and one and two hoe-weedings at 4 and 3 and 6WAS, each of which gave similar and produced more number of leaves/plant than the weedy check.

At Afaka and at 3WAS, oxadiazon at 2.0 kg a.i /ha gave more number of leaves/plant than all the other treatments.This was followed by diuron at 2.5 kg a.i /ha, butachlor at 2.0 kg a.i /ha and one and two hoe-weeding at 4 and 3 and 6WAS, each of which was similar and produced more number of leaves/plant than the rest of the treatments including the weedy check. At 6WAS, three hoe-weedings resulted in more number of leaves/plant than all the

Table 20: Effects of weed control methods on number of leaves/plant in roselleduring thewet seasonof 2012, at Samaru and Afaka

		Number of leaves/plant							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3 WAS	6 WAS	9 WAS	12 WAS	3 WAS	6 WAS	9 WAS	12 WAS
Oxadiazon	1.5	29.67bc	41.33ef	76.33bcd	98.33b	35.00d	55.67b-e	72.33fgh	96.33cd
Oxadiazon	2.0	27.33bc	35.00g	72.33cd	101.00b	46.00a	56.67bcd	71.33ghi	92.33def
Diuron	2.0	17.33d	22.67i	70.00d	106.60a	38.33c	48.67e	64.00jk	86.33efg
Diuron	2.5	26.33c	35.67g	73.00bcd	104.67a	41.67b	62.33ab	82.33c	97.67cd
Metolachlor	1.5	27.67bc	41.67ef	72.00bcd	100.67b	26.00f	56.00b-e	70.00hi	101.00bcd
Metolachlor	2.0	27.33bc	42.33def	76.00bcd	102.67b	32.33e	51.00cde	60.33k	95.33c-f
Butachlor	1.5	27.00c	45.00cde	74.33bcd	106.33a	33.33d	50.00cde	73.33e-h	103.33bcd
Butachlor	2.0	30.00bc	38.67fg	70.33cd	105.00a	40.67b	55.00b-e	82.00cd	102.33bcd
Pendimethalin	1.5	36.33a	50.00ab	75.33bcd	108.00a	38.77c	57.00bc	67.00ij	105.00abc
Pendimethalin	2.0	32.33ab	49.67abc	79.33bcd	110.00a	38.33c	55.67b-e	75.67efg	107.33ab
HW @ 4WAS	-	27.67bc	43.33def	70.33cd	99.00b	40.67b	50.67cde	77.00def	88.00efg
HW @ 3&6 WAS	-	29.00bc	46.67bcd	80.33ab	98.33b	40.33b	62.33ab	88.33b	101.00bcd
HW @ 3,6&9WAS	-	26.67c	53.33a	86.67a	109.67a	38.33c	67.67a	96.00a	111.00a
Weedy check	-	20.33d	29.67h	50.67e	67.00c	34.67d	49.33de	78.00cde	82.33g
SE+		0.892	0.882	1.572	2.609	0.730	1.315	0.955	1.719

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

other treatments, except diuron at 2.5 kg a.i /ha and hoe-weeding at 3 and 6WAS. At 9WAS, three hoe-weedings at 3, 6 and 9WAS produced more number of leaves/plant than all the other treatments. Two hoe-weeding at 3 and 6WAS gave more number of leaves/plant than the rest of the treatments. Three hoe-weedings resulted in more number of leaves/plant than all the other treatments, except pendimethalin at two given rates when data was taken at 12WAS.

4.4.7 Number of primary branches/plant

The effects of weed control methods on number of primary branches/plant at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 21 and 22**.** At 3WAS in 2011 at Samaru (Table 21), pendimethalin at 1.5 kg a.i /ha produced more number of primary branches/plant than all treatments, with exception of diuron, at the two available rates as well as the weedy check.All the other treatments were similar to both the highest and lowest values. At 6WAS, one and three hoe-weedings at 4 and at 3, 6 and 9WAS resulted in greater number of primary branches/plant than all the herbicide treatments, except pendimethalin at the two given rates. At 9WAS, three hoe-weedings at 3,6and 9WAS, produced more number of primary branches/plant than all the other treatments, except two hoe-weeding at 3 and 6WAS. At 12WAS, three hoe-weedings at 3, 6 and 9WAS, gave more number of primary branches/plant than all the other treatments, followed by two hoe-weedings at 3 and 6WAS, pendimethalin at 2.0 kg a.i /ha and metolachlor at 1.5 kg a.i /ha, each of which produced more number of primary branches/plant than the rest.

In 2011 at Afaka and at 3WAS, pendimethalin at 2.0 kg a.i /ha gave more branches than the other treatments with diuron at the two given rates and hoe-weeding at 3 and 6WAS. At

Table 21: Effects of Weed Control Methods on Number of Primary Branches/plant of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Number of primary branches/plant							
		Samaru				Afaka			
Treatment	Rates (kga.i/ha	3 WAS	6 WAS	9 WAS	12 WAS	3 WAS	6 WAS	9 WAS	12 WAS
Oxadiazon	1.5	2.00abc	4.33bcd	6.00e-h	9.00bcd	1.00ab	2.00ab	2.67bcd	3.00cde
Oxadiazon	2.0	2.00abc	4.00cde	5.00gh	10.33bc	1.00ab	1.67ab	3.00bcd	4.67bcd
Diuron	2.0	1.33c	2.67e	5.00gh	7.67d	0.10c	0.10c	0.10e	0.10g
Diuron	2.5	1.67bc	3.33de	4.67h	8.67bcd	0.10c	0.10c	0.10e	0.10g
Metolachlor	1.5	2.67ab	5.00abc	5.67fgh	10.67b	1.33ab	2.33a	3.00bcd	4.00b-e
Metolachlor	2.0	2.33abc	4.00cde	7.00c-f	10.00bc	1.00ab	1.67ab	3.00bcd	3.67cde
Butachlor	1.5	2.00abc	4.33bcd	6.67c-g	9.00bcd	1.00ab	2.00ab	3.00bcd	3.33cde
Butachlor	2.0	2.00abc	4.33bcd	6.33e-h	9.00bcd	1.33ab	1.67ab	4.00abc	4.00b-e
Pendimethalin	1.5	3.00a	5.63ab	8.33bc	8.67bcd	1.33ab	2.00ab	3.67abc	4.00b-e
Pendimethalin	2.0	2.00abc	5.67ab	7.67b-e	10.67b	1.67a	2.33a	4.33ab	5.00abc
HW @ 4WAS	-	2.00abc	6.00a	8.00bcd	8.33cd	1.00ab	1.33b	1.67d	2.67ef
HW @ 3&6WAS	-	2.67ab	5.67ab	9.33ab	10.67b	0.67b	2.00ab	4.00abc	5.33ab
HW@ 3 ,6&9WAS	-	2.33abc	6.00a	10.67a	13.33a	1.00ab	2.00ab	4.67a	6.00a
Weedy check	-	1.67bc	2.67e	5.67fgh	7.67d	1.33ab	1.33b	2.00d	2.33f
SE$\pm$	-	0.270	0.175	0.320	0.378	0.156	0.136	0.233	0.236

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

6WAS, metolachlor at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i /ha gave similar and more number of primary branches/plant than the two treatments with diuron as well as one hoe-weeding at 4WAS and weedy check.. Each other treatment was comparable to the least and highest values. At 9WAS, three hoe-weedings at 3, 6 and 9WAS resulted in more number of primary branches/plant than all other treatments, except treatments with pendimethalin, butachlor each at 2.0 kg a.i /ha and hoe-weeding at 3 and 6WAS. The two rates of diuron (2.0 and 2.5 kg a.i /ha) gave the least number of branches, that were lower than by the weedy check. At 12WAS, three hoe-weedings at 3, 6 and 9WAS gave the highest branches numbers than all the other treatments, except two hoe-weeedings at 3 and 6 WAS. Diuron at both rates consistently gave the least number of primary branches than all the other treatment, including the weedy check.

At 3WAS in 2012 at Samaru (Table 22), all treatments resulted in similar number of primary branches/plant. At 6WAS, metolachlor and butachlor each at 1.5 kg a.i /ha and 2.0 kg a.i /ha and pendimethalin at 1.5 kg a.i /ha enhanced primary branching over the weedy check.Other treatments were comparable to the least and maximum values in the trial. At 9WAS, two hoe-weeding at 3and 6WAS produced more number of primary branches/plant than the weedy check, each rate of oxadiazon and diuron. At 12WAS one and three hoe-weedings, treatments with oxadiazon and pendimethalin each at two given rates and butachlor at 2.0 kg a.i /ha gave more number of primary branches/plant than the weedy check. The other treatments were at *par* with these treatments except the weedy check.

At 3WAS in 2012 at Afaka (Table 22), pendimethalin and metolachlor, each at 2.0 kg a.i /ha resulted in similar and higher number of primary branches/plant than the weedy check. At 6WAS, all treatments resulted in higher number of primary branches than the weedy check, except each of the two rates of diuron and oxadiazon, and hoe-weeding at 3 and

Table 22: Effects of Weed Control Methods on Number of Primary Branches/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

Treatment	Rates (kga.i/ha)	**Number of primary branches/plant** Samaru 3 WAS	6 WAS	9 WAS	12 WAS	Afaka 3 WAS	6 WAS	9 WAS	12 WAS
Oxadiazon	1.5	2.33	5.00ab	8.00bcd	12.67a	1.00abc	3.00abc	4.00bc	6.33bcd
Oxadiazon	2.0	1.67	5.00ab	8.00bcd	13.00a	0.67bc	3.00abc	4.67abc	6.33bcd
Diuron	2.0	2.00	4.00ab	8.33a-d	10.00ab	1.00abc	3.00abc	4.33abc	6.33bcd
Diuron	2.5	1.33	4.67ab	7.00cd	11.00ab	1.00abc	2.67bc	4.00bc	6.33bcd
Metolachlor	1.5	2.00	5.67a	8.00bcd	10.33ab	1.33ab	3.67ab	4.33abc	7.33ab
Metolachlor	2.0	2.33	5.67a	8.33a-d	11.00ab	1.67a	3.67ab	5.00ab	7.00bc
Butachlor	1.5	2.00	5.33a	8.33a-d	11.00ab	1.00abc	4.00a	4.33abc	7.33ab
Butachlor	2.0	2.33	5.67a	8.67a-d	11.67a	1.33ab	4.00a	5.00ab	7.00bc
Pendimethalin	1.5	2.67	5.33a	9.00a-d	12.00a	1.33ab	4.00a	5.33ab	7.67ab
Pendimethalin	2.0	2.67	4.67ab	9.33abc	11.67a	1.67a	3.67ab	5.33ab	7.00bc
Hw @4 WAS	-	2.33	4.33ab	9.33abc	11.67a	1.00abc	3.33ab	3.33c	5.67cd
Hw @3&6WAS	-	2.33	4.67ab	10.67a	10.67ab	1.00abc	3.00abc	5.33ab	7.00bc
HW @ 3,6,9WAS	-	2.00	4.67ab	9.67ab	12.00a	1.00abc	3.67ab	5.67a	8.67a
Weedy check	-	1.67	3.00b	6.67d	7.67b	0.33c	2.00c	3.33c	5.33d
SE±	-	0.231	0.372	0.431	0.628	0.138	0.191	0.231	0.267

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

6WAS. At 9WAS, three hoe-weeding at 3,6 and 9WAS, pendimethalin at the two available rates, butachlor and metolachlor each at 2.0 kg a.i /ha and two hoe-weeding at 3 and 6WAS gave higher number of primary branches than the weedy check, hoe-weeding at 4WAS and diuron at 2.5 kg a.i /ha. At 12WAS, three hoe-weeding at 3, 6 and 9WAS resulted in more number of primary branches/plant than all the other treatments, except metolachlor, butachlor and pendimethalin, each at1.5 kg a.i /ha.

4.4.8 Number of secondary branches/plant

The effects of weed control methods on number of secondary branches/plant at 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are presented in Tables 23 and 24. At 6WAS 2011 at Samaru (Table 23), treatments with pendimethalin at 2.0 kg a.i /ha and two and three hoe-weedings gave similar number of secondary branches/plant than all the other treatments. At 9WAS, three hoe-weedings resulted in more number of secondary branches/plant than all the other treatments except hoe-weeding at 3and 6WAS and the treatment with pendimethalin at 2.0 kg a.i /ha, which in turn were higher than trearments with oxadiazon, diuron and the weedy check. The greatest number of secondary branches/plant was produced by the three hoe-weedings at 3, 6 and 9WAS, which was higher than all the other treatments, except treatment with pendimethalin at the two given rates and two hoe-weeding at 3and 6WAS when sampled at 12WAS.

In 2011 at Afaka and at 6WAS, pendimethalin at 2.0 kg a.i /ha gave more number of secondary branches/plant than all the other treatments, except pendimethalin at 1.5 kg a.i /ha, and two and three hoe-weedings which in turn produced more number of secondary branches/plant than the remaining treatments except the two rates of metolachlor. At 9WAS, pendimethalin at the two given rates, butachlor at 2.0 kg a.i /ha and two and three hoe-weeding resulted in similar and gave more number of secondary branches/plant than all

Table 23: Effects of Weed Control Methods on Number of Secondary Branches/plant of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Number of secondary branches/plant					
		Samaru			Afaka		
Treatment	Rates(kg a.i/ha)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	3.67def	4.67f	7.67cd	1.33d	2.33ab	4.00bc
Oxadiazon	2.0	3.67def	4.67f	7.67cd	1.33d	2.33ab	4.67b
Diuron	2.0	3.00fg	4.67f	6.67d	0.10e	0.10c	0.10d
Diuron	2.5	3.00fg	4.67f	6.67d	0.10e	0.10c	0.10d
Metolachlor	1.5	4.33cd	7.33bcd	9.33bc	2.33abc	2.67ab	4.33bc
Metolachlor	2.0	4.00de	7.33bcd	9.33bc	2.33abc	3.00ab	4.33bc
Butachlor	1.5	4.00de	6.33de	8.33cd	1.67cd	3.33ab	4.33bc
Butachlor	2.0	3.33efg	6.67cd	8.67bcd	2.00bcd	3.67a	4.33bc
Pendimethalin	1.5	5.67ab	7.67abc	10.33ab	2.67ab	3.67a	5.67ab
Pendimethalin	2.0	6.00a	8.33ab	10.33ab	3.00a	3.67a	5.67ab
HW @ 4WAS	-	5.00bc	5.33ef	7. 33d	2.00bcd	2.67ab	2.67c
HW @ 3&6WAS	-	5.67ab	8.00ab	10.33ab	2.67ab	4.00a	5.67ab
HW@ 3 ,6& 9 WAS	-	6.00a	8.67a	12.00a	2.67ab	4.00a	6.67a
Weedy check	-	2.67g	4.33f	6.67d	1.33d	1.67b	2.67c
SE±	-	0.169	0.227	0.348	0.167	0.307	0.323

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

the other treatments, except metolachlor at the two given rates, butachlor at 1.5 kg a.i /ha and one hoe-weeding at 4WAS, each of which was similar and produced more number of secondary branches/plant than diuron at the two available rates and weedy check. At 12WAS, three hoe-weeding at 3, 6 and 9WAS resulted in more number of secondary branches/plant than all the other treatments, except pendimethalin at the two available rates and two hoe-weeding at 3 and 6WAS. The least number of secondary branches/plant was obtained by diuron at the two given rates.

In 2012 at Samaru and at 6WAS (Table 24), three hoe-weedings gave more number of secondary branches/plant than all the other treatments. At 9WAS, three hoe-weeding resulted in more number of secondary branches/plant than all the other treatments, except pendimethalin at 1.5 kg a.i /ha which in turn gave higher number of secondary branches/plant than the rest of the treatments. The greatest number of secondary branches/plant was by hoe-weeding at 3, 6 and 9WAS which was higher than all the other treatments, except pendimethalin and metolachlor, each at 2.0 kg a.i /ha when data was taken at 12 WAS.

In 2012 atAfakaandat 6WAS, three hoe-weeding at 3, 6 and 9WAS gave more number of secondary branches/plant than all the other treatments, except two hoe-weeding at 3 and 6 WAS which in turn produced more number of secondary branches/plant than the rest of the treatments. At 9WAS, pendimethalin at 1.5 kg a.i /ha and three hoe-weedings resulted in similar and produced more number of secondary branches/plant than all the other treatments, except pendimethalin at 2.0 kg a.i /ha which in turn gave higher number of secondary branches/plant than the rest of the treatments. Pendimethalin at 1.5 kg a.i /ha resulted in greater number of secondary branches/plant than all the other treatments, except metolachlor at the two given rates, butachlor and pendimethalin each at 2.0 kg a.i./ha and

Table 24: Effects of Weed Control Methods on Number of Secondary Branches/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Number of secondary branches/plant					
		Samaru			Afaka		
Tresatment	Rates(kga.i/ha)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	13.00fg	15.67f	23.33efg	3.33ef	6.67def	10.33bc
Oxadiazon	2.0	18.00cde	22.67cde	29.67bcd	2.67f	6.67def	10.00c
Diuron	2.0	14.00fg	16.00f	29.67bcd	5.00cd	5.67fg	10.00c
Diuron	2.5	15.67efg	25.33bc	31.33bc	2.33f	5.00gh	10.67bc
Metolachlor	1.5	18.67cde	23.00cde	31.00bcd	4.67cd	8.67bc	13.33abc
Metolachlor	2.0	23.00b	22.67cde	34.00ab	5.00cd	8.67bc	13.00abc
Butachlor	1.5	13.67fg	21.00de	27.67cde	4.33de	7.00de	10.33bc
Butachlor	2.0	14.33fg	20.67e	29.67bcd	5.00cd	7.67cd	14.00abc
Pendimethalin	1.5	20.67bc	27.00ab	32.67bc	5.67bc	10.00a	17.33a
Pendimethalin	2.0	16.67def	25.00bcd	34.00ab	5.33cd	9.67ab	12.67abc
HW @ 4 WAS	-	19.67bcd	22.00cde	25.67def	5.00cd	6.00ef	11.33bc
HW @ 3& 6WAS	-	19.67bcd	23.00cde	32.67bcd	6.67ab	8.67bc	15.33ab
HW @ 3,6,&9WAS	-	26.67a	30.33a	37.67a	7.33a	10.33a	12.67abc
Weedy check	-	12.33g	17.00f	19.67g	4.33de	4.67h	10.00c
SE$\pm$		0.661	0.715	0.976	0.213	0.189	0.669

WAS: Weeks after sowing

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

two and three hoe-weedings; each was in turn higher than the rest of the treatments when sampled at 12WAS.

4.4.9 Number of tertiary branches/plant

The effects of weed control methods on number of tertiary branches/plant at 6, 9 and 12 WAS of roselle during wet seasons of 2011and 2012 at Samaru and Afaka are presented in Tables 25 and 26. In 2011 Samaru at 6WAS (Table 25), pendimethalin at 1.5 kg a.i /ha and two hoe-weedings at 3 and 6WAS gave similar and produced more number of tertiary branches/plant than the weedy check and all the other herbicide treatments, except pendimethalin at 2.0 kg a.i /ha, butachlor at 2.0 kg a.i/ ha and hoe-weedings at 3, 6 and 9 WAS. At 9WAS, hoe-weedings at 3, 6 and 9WAS gave greater number of tertiary branches/plant than all the other treatments, except pendimethalin at 1.5 and 2.0 kg a.i /ha and two hoe-weeding at 3 and 6WAS. At 12WAS, the three hoe-weedings at 3, 6 and 9WAS resulted in more number of tertiary branches/plant than all the other treatments, except the two available rates of pendimethalin, each of which was higher than values by treatments with oxadiazon and diuron and the weedy check.

At Afaka and at 6WAS, treatment with metolachlor at 2.0 kg a.i /ha, pendimethalin at the two available rates, oxadiazon at 1.5 kg a.i /ha and two and three hoe-weedings at 3and6 and 3, 6 and 9 WAS, respectively, gave similar and more number of tertiary branches/plant than the rest of the treatment except butachlor at the two available rates and oxadiazon at 2.0 kg a.i /ha. The two rates of diuron resulted in least values, which were lower than by the weedy check. At 9WAS, metolachlor and pendimethalin each at 2.0 kg a.i /ha gave higher tertiary branches/plant than the weedy check and treatments by diuron which gave the least values in the trial, but was comparable to all other weed control treatments except oxqdiazon at 2.0 kg a.i ha. At 12WAS, the two and three hoe-weedings at 3 and 6 and 3, 6

Table 25: Effects of Weed Control Methods on Number of Tertiary Branches/plant of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Number of tertiary branches/plant					
		Samaru			Afaka		
Treatment	Rates (kga.i/ha)	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	2.33de	3.00def	5.00de	2.33a	2.33abc	3.00bc
Oxadiazon	2.0	2.00de	3.00def	5.67cde	1.67ab	1.67bc	3.00bc
Diuron	2.0	1.07e	2.33f	5.67cde	0.10c	0.10d	0.10d
Diuron	2.5	2.00de	3.00def	5.67cde	0.10c	0.10d	0.10d
Metolachlor	1.5	2.00de	4.00bcd	7.33b	1.33b	2.33abc	4.00b
Metolachlor	2.0	3.00bcd	3.67cde	7.00bc	3.33a	3.33a	4.00b
Butachlor	1.5	2.67cde	4.00bcd	6.33bcd	2.00ab	2.67abc	3.00bc
Butachlor	2.0	3.33abc	3.67cde	7.00bc	2.00ab	3.00ab	3.00bc
Pendimethalin	1.5	4.00a	4.67abc	7.67ab	2.67a	3.00ab	4.00b
Pendimethalin	2.0	3.67ab	5.00ab	7.67ab	2.33a	3.33a	4.00b
HW @ 4 WAS	-	2.67cde	3.67cde	4.67e	1.33b	2.33abc	2.67bc
HW @3&6WAS	-	4.00a	5.00ab	7.00bc	2.67a	2.67abc	6.33a
HW @ 3,6&9WAS	-	3.33abc	5.33a	8.67a	3.00a	3.00ab	7.33a
Weedy check		1.67e	2.67ef	4.67e	1.33b	1.33cd	1.67c
SE$\pm$		0.177	0.186	0.242	0.423	0.260	0.252

WAS: Weeks after sowing

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMR.

and 9WAS, respectively resulted in similar and more number of tertiary branches/plant than all the other treatments including the weedy check, followed by treatments with pendimethalin and metolachlor, each at the two available rates, which in turn gave more number of tertiary branches/plant than the weedy check and diuron at two available rates.

At 6WAS in 2012 at Samaru, (Table 26), three hoe-weedings at 3, 6and 9WAS, gave more number of tertiary branches/plant than all the other treatments, followed by pendimethalin at 2.0 kg a.i /ha, which in turn resulted in more number of tertiary branches than the rest, except two hoe-weeding at 3 and 6WAS and pendimethalin at 1.5 kg a.i /ha. The treatment with oxadiazon at 1.5 kg a.i /ha and three hoe-weedings at 3, 6and 9WAS produced more number of tertiary branches/plant than all the other treatments, except treatments with pendimethalin and two hoe-weeding when sampled at 9WAS. At 12WAS, treatments with oxadiazon at 1.5kg a.i /ha, pendimethalin at 2.0kg a.i /ha and three hoe-weeding at 3, 6and 9WAS resulted in similar and more number of tertiary branches/plant than all the other treatments, except metolachlor at the two available rates and oxadiazon at 2.0 kg a.i /ha. The weedy check consistently gave the least number of branches in this trial.

An Afaka and at 6WAS, metolachlor at 2.0kg a.i /ha, pendimethalin at the two given rates and one hoe-weeding at 4WAS, gave similar number of tertiary branches/plant, each of which was higher than by diuron at 2.0 and 2.5 kg a.i /ha and the weedy check. At 9WAS, hoe-weedings at 3, 6 and9WAS and pendimethalin at 2.0kg a.i /ha produced similar and number of tertiary branches/plant than all the other treatments, except pendimethalin and metolachlor, each at 2.0kg a.i /ha and two hoe-weeding at 3and 6WAS.The two rates of diuron and the weedy check gave the least branch numbers. At 12WAS, three hoe-weedings at 3, 6 and 9WAS gave more number of tertiary branches/plant than all the other

Table 26: Effects of Weed Control Methods on Number of Tertiary Branches/ plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

		Number of tertiary branches/plant					
		Samaru			Afaka		
Treatment	Rates (kg a.i/ha	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	3.33d	8.67a	10.33a	2.00ab	4.33bc	6.67b-e
Oxadiazon	2.0	3.00d	6.67c	10.00ab	2.33ab	3.33cde	6.67b-e
Diuron	2.0	2.00e	6.67c	7.67e	1.33b	2.33def	6.00b-f
Diuron	2.5	2.00e	5.33d	8.00de	1.33b	1.67f	5.33c-f
Metolachlor	1.5	3.67d	7.33bc	10.00ab	2.67ab	4.67bc	7.00a-d
Metolachlor	2.0	3.33d	7.33bc	10.00ab	3.00a	5.33ab	7.00a-d
Butachlor	1.5	3.00d	6.67c	8.67cde	2.00ab	3.33cde	5.67b-f
Butachlor	2.0	3.33d	7.00c	9.00bcd	2.00ab	3.67cd	5.00def
Pendimethalin	1.5	4.67bc	8.33ab	9.67abc	3.33a	5.67ab	7.33abc
Pendimethalin	2.0	5.00b	7.67abc	10.33a	3.33a	6.33a	7.67ab
HW @ 4 WAS	-	4.00cd	5.33d	6.67f	3.00a	3.67cd	4.33ef
HW@ 3&6WAS	-	4.67bc	7.67abc	8.00de	2.67ab	5.67ab	6.33a-e
HW@3,6&9WAS	-	6.00a	8.67a	10.33a	2.67ab	6.67a	8.33a
Weedy check		2.00e	3.33e	4.00g	1.33b	2.00ef	4.00f
SE$\pm$		0.176	0.189	0.196	0.246	0.260	0.393

WAS: Weeks after sowing
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

treatments including the weedy check, except treatments with pendimethalin at 2.0 kg a.i/ha.

4.4.10 Stem girth (mm)

The effects of weed control methods on stem girth at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 27 and 28. In 2011 at Samaru at 3WAS (Table 27), treatments with oxadiazon and diuron and the weedy check resulted in lower stem girth than all the other treatments. At 6WAS, pendimethalin at 2.0 kg a.i /ha gave thicker stem than all other treatments, followed by the pendimethalin at 1.5 kg a.i /ha which gave thicker stem than the remaining treatments. At 9WAS, three hoe-eedings at 3, 6 and 9WAS resulted in thicker stem than all the other treatments, followed by the pendimethalin and metolachlor, each at the two given rates and two hoe-weeding at 3and 6 WAS, each of which gave thicker stem than the rest of the treatment. At 12WAS, three hoe-weedings at 3, 6and 9WAS gave thicker stem than all the other treatments but was comparable to metolachlor and pendimethalin each at two given rates and butachlor at 2.0 kg a.i /ha.

At Afaka and at 3WAS, pendimethalin at the two available rates and two and three hoe-weedings at 3and6 and 3, 6and9WAS, respectively resulted in similar stem girth each of which was thicker than all the other treatments, except butachlor and metolachlor, each at 2.0 kg a.i /ha and one hoe-weeding at 4WAS. At 6WAS, two and three hoe-weedings and pendimethalin at the two given rates produced similar stem girth, each of which was greater than all the other treatments, followed by one hoe-weeding at 4WAS,which was thicker than the rest. At 9WAS hoe-weedings at 3, 6 and 9WAS and metolachlor at 2.0 kg a.i /ha gave similar thicker stem than the other treatments, followed by pendimethalin at the two given rates, each of which was thicker than the rest. At 12WAS, hoe-weedings at 3, 6 and

Table 27: Effects of Weed Control Methods on Stem Girth (mm) of Roselle during Wet Season of 2011, at Samaru and Afaka.

		Stem girth (mm)							
		Samaru				Afaka			
Treatment	Rates (kg a.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	2.60bc	3.20f	4.00e	4.00de	1.13de	1.43de	1.97efg	2.40f
Oxadiazon	2.0	2.63b	3.20f	4.00e	4.00de	1.07e	1.43de	1.93fg	2.40f
Diuron	2.0	2.37d	2.67h	3.50g	4.13cde	0.10f	0.10f	0.10h	0.10g
Diuron	2.5	2.40cd	2.73g	3.47g	4.13cde	0.10f	0.10f	0.10h	0.10g
Metolachlor	1.5	3.03a	3.60d	4.54b	4.77a-d	1.33bc	1.60bcd	2.20cd	2.60de
Metolachlor	2.0	3.07a	3.60d	4.57b	5.13abc	1.40ab	1.63bc	2.67a	2.63d
Butachlor	1.5	3.07a	3.40e	4.23d	4.43b-e	1.30bc	1.53cde	2.00ef	2.50ef
Butachlor	2.0	3.07a	3.40e	4.33c	4.87a-d	1.37ab	1.53cde	2.00ef	2.60de
Pendimethalin	1.5	3.13a	3.80b	4.67b	5.17abc	1.47a	1.97a	2.40b	2.97b
Pendimethalin	2.0	3.13a	3.90a	4.67b	5.17abc	1.50a	1.98a	2.40b	3.03b
HW @ 4WAS	-	3.13a	3.63cd	4.23d	4.43b-e	1.40ab	1.73b	2.33de	2.43f
HW@ 3&6WAS	-	3.13a	3.63cd	4.57b	4.60bcd	1.50a	2.07a	2.33de	2.83c
HW@ 3,6&9WAS	-	3.13a	3.67c	4.93a	5.33ab	1.50a	2.07a	2.67a	3.33a
Weedy check	-	2.60bc	2.76g	3.63f	3.70cde	1.23cd	1.37e	1.83g	2.53de
SE$\pm$		0.043	0.011	0,019	0.182	0.024	0.033	0.034	0.019

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

9WAS gave thicker stem than all the other treatments, followed by pendimethalin at the two available rates which were similar and gave thicker stem than the remaining treatments. In 2012 at Samaru and at 3WAS, (Table 28), pendimethalin at the two given rates, metolachlor at 2.0 kg a.i /ha, and the three hoe- weedings resulted in thicker stems than each treatment with oxadiazon and diuron, metolachlor at 1.5 kg a.i /ha and the weedy check. At 6WAS, three hoe-weedings at 3,6 and 9WAS gave significantly thicker stem than all the other treatments, followed by pendimethalin at 2.0kg a.i /ha, which in turn gave thicker stem than the rest. At 9WAS, pendimethalin at 2.0kg a.i /ha gave thicker stem compared to all the other treatments, except three hoe-weedings at 3,6and9WAS which in turn was thicker than the rest. At 12WAS, three hoe-weedings gave thicker stem than all the other treatments; this was followed by pendimethalin at 2.0 kg a.i /ha, which in turn gave thicker stem than the rest of the treatments.The weedy check consistently gave the least stem girth in the trial.

At Afaka and at 3WAS, hoe-weedings at 3,6 and 9WAS gave thicker stem than all the other treatments, except pendimethalin at the two available rates. At 6WAS, pendimethalin at the two given rates resulted in similar and gavethicker stem than all the other treatments, except two hoe-weeding at 3 and6WAS. The two and three hoe-weedings and pendimethalin at the two given rates resulted in similar and gavethicker stem girth than all the other treatments, except metolachlor at 2.0 kg a.i /ha, when data was taken at 9WAS. At 12WAS, three hoe-weedings gave thicker stem than all the other treatments, followed by pendimethalin at 1.5 kg a.i /ha which in turn resulted in thicker stem than the rest of the treatments.

Table 28: Effects of Weed Control Methods on Stem Girth (mm) of Roselle during Wet Season of 2012, at Samaru and Afaka

		Stem girth (mm)							
		Samaru				Afaka			
Treatment	Rates(kga.i/ha)	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Oxadiazon	1.5	3.00cd	3.40fg	3.93g	4.33f	2.13f	2.60b-e	2.93efg	3.40g
Oxadiazon	2.0	3.00cd	3.50f	4.00g	4.40f	2.13f	2.53cde	2.87fg	3.30g
Diuron	2.0	2.80d	3.37g	3.67i	4.23g	1.87gh	2.40de	2.73g	3.33h
Diuron	2.5	2.80d	3.37g	3.80h	4.30f	1.67h	2.40de	2.77g	3.00i
Metolachlor	1.5	3.13bc	4.13c	4.50cd	5.10c	2.33e	2.80abc	3.30bc	3.77de
Metolachlor	2.0	3.47a	4.20bc	4.57c	5.13c	2.47d	2.80abc	3.47ab	3.70ef
Butachlor	1.5	3.37ab	3.83e	4.27f	4.80d	2.40de	2.60b-e	3.03def	3.67ef
Butachlor	2.0	3.37ab	3.87de	4.37e	4.87d	2.40de	2.63bcd	3.10cde	3.60f
Pendimethalin	1.5	3.47a	4.20bc	4.67b	5.20bc	2.67ab	3.00a	3.53a	4.07b
Pendimethalin	2.0	3.47a	4.27b	4.80a	5.27b	2.70ab	3.03a	3.57a	3.97bc
HW @ 4 WAS	-	3.47a	3.97d	4.27f	4.53e	2.50cd	2.67bcd	3.23cd	3.00i
HW @ 3&6WAS	-	3.47a	4.13c	4.47d	5.17bc	2.60bc	2.90ab	3.53a	3.87cd
HW @ 3,6&9 WAS	-	3.47a	4.53a	4.73ab	5.53a	2.77a	2.83abc	3.70a	4.37a
Weedy check	-	2.73e	3.13i	3.47j	3.80h	2.00g	2.30e	2.47h	2.80j
SE$\pm$		0.054	0.022	0.019	0.024	0.021	0.054	0.042	0.023

WAS: Weeks after sowing

Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

4.4.11 Days to 50% flowering

The effects of weed control methods on number of days to 50% flowering of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka is shown in Table 29.Weed control treatments significantly influenced the number of days to 50% flowering in roselle in 2012 at Samaru and 2011 at Afaka only. In 2012 at Samaru, all the weed control treatments resulted in similar and less number of days to 50% flowering than the weedy check and butachlor at 2.0 kg a.i /ha. In 2011 at Afaka, pendimethalin at 2.0 kg a.i /ha and two and three hoe-weedings resulted in prolonged period to 50% flowering,compared to the two rates each of diuron, metolachlor , oxadiazon at 1.5 kg a.i/ha and the weedy check.

4.4.12 Days to physiological crop maturity

The effects of weed control methods on days to physiological crop maturity of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka is presented in Table 30. Weed control treatments significantly influenced the days to physiological crop maturity in roselle in both locations and years of study. In 2011 at Samaru, butachlor at 2.0kg a.i /ha gave longer period of days to physiological crop maturity than oxadiazon at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i /ha. In 2012 in this location, butachlor at 2.0 kg a.i /ha and the weedy check gave longer period of days to physiological crop maturity than all the other treatments.

In 2011 at Afaka, pendimethalin at 2.0kg a.i /ha, two and three hoe-weedings resulted in prolonged period of days to physiological crop maturity compared to oxadiazon at 1.5 kg a.i /ha, diuron and metolachlor, each at the two given rates and the weedy check. In 2012, oxadiazon at 1.5 kg a.i /ha resulted in longer periods of days to physiological crop maturity than diuron, metolachlor and butachlor, each at 1.5 kg a.i /ha, butachlor and pendimethalin, each at 2.0 kg a.i /ha and one hoe-weeding at 4WAS.

Table 29: Effects of Weed Control Methods on Days to 50% Fowering of Roselle during Wet Sasons of 2011 and 2012 at Samaru and Afaka

		Days to 50% flowering			
		Samaru		Afaka	
Treatment	Rates (kg a.i/ha)	2011	2012	2011	2012
Oxadiazon	1.5	89.00	89.00b	90.00b	89.00
Oxadiazon	2.0	89.00	89.00b	90.33ab	89.00
Diuron	2.0	90.00	89.00b	0.10c	89.00
Diuron	2.5	91.33	89.00b	0.10c	89.00
Metolachlor	1.5	89.33	89.33b	90.00b	89.33
Metolachlor	2.0	90.00	89.33b	90.00b	89.00
Butachlor	1.5	89.33	89.33b	90.33ab	89.00
Butachlor	2.0	89.33	90.33a	90.33ab	89.00
Pendimethalin	1.5	89.33	89.00b	90.33ab	90.00
Pendimethalin	2.0	89.00	89.00b	91.00a	90.00
HW @ 4WAS	-	90.00	89.00b	90.67ab	89.00
HW@3&6WAS	-	90.33	89.33b	91.00a	89.33
HW@3,6,&9WAS	-	89.33	89.33b	91.00a	89.00
Weedy check	-	89.00	90.00a	90.00b	89.33
SE$\pm$	-	0.487	0.113	0.149	0.467

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 30: Effects of Weed Control Methods on days to Physiological Crop Maturity of Roselle during Wet Seasons of 2011 and 2012, at Samaru and Afaka

		Days to physiological crop maturity			
		Samaru		Afaka	
Treatment	Rates (kg a.i/ha)	2011	2012	2011	2012
Oxadiazon	1.5	130.00b	130.00b	132.00b	131.33a
Oxadiazon	2.0	130.33ab	130.00b	132.33ab	130.67ab
Diuron	2.0	130.67ab	130.00b	0.10c	130.00b
Diuron	2.5	130.67ab	130.00b	0.10c	130.33ab
Metolachlor	1.5	130.33ab	130.33b	132.00b	130.00b
Metolachlor	2.0	130.67ab	130.33b	132.00b	130.33ab
Butachlor	1.5	130.33ab	130.33b	132.33ab	130.00b
Butachlor	2.0	131.00a	131.33a	132.33ab	130.00b
Pendimethalin	1.5	130.67ab	130.00b	132.33ab	130.33ab
Pendimethalin	2.0	130.00b	130.00b	133.00a	130.00b
HW@ 4WAS	-	130.67ab	130.00b	132.67ab	130.00b
HW@3&6WAS	-	130.33ab	130.33b	133.00a	130.33ab
HW@3,6&9WAS	-	130.33ab	130.33b	133.00a	130.33ab
Weedy check	-	130.67ab	131.00a	132.00b	130.00b
SE$\pm$	-	0.120	0.113	0.149	0.212

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

4.5 Yield and Yields Components

4.5.1 Number of calyx/plant

The effects of weed control methods on number of calyx/plant of roselle during wet seasons of 2011and 2012 and the combined data at Samaru and Afaka is shown in Table 31. At Samaru, three hoe-weedings at 3, 6 and 9WAS consistently gave more number of calyx/plant than all the other treatments in both years and the combined data. Following this was pendimenthalin at 2.0 kg a.i /ha in the two years and combined, metolachlor and pendimethalin each at 1.5 kg a.i /ha in 2012. These treatments gave more calyx than the rest in the respective year and combined data. The least number of calyx was consistently by the weedy check.

At Afaka, three hoe-weedings also consistently gave the highest number of calyx which was higher than all the other treatments. This was followed by pendimethalin at 1.5 kg a.i /ha in the two years and combined data and metolachlor at 1.5 kg a.i/ha and pendimethalinat 2.0 kg a.i /ha and hoe-weeding at 3 and 6WAS in 2012. Diuron at 2.5 kg a.i/ha consistently gave the least number of calyx.

4.5.2 Calyx weight/plant (g)

The effects of weed control method on calyx weight/plant of roselle during wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka is presented in Table 32. In 2011 Samaru, three hoe-weeding gave higher calyx weight/plant than all the other treatments. This was followed by treatment with pendimethalin at 1.5 kg a.i/ha which in turn gave higher calyx weight than the rest of the treatments, except treatment with metolachlor at the two given rates, butachlor at 1.5 kg a.i/ha, pendimethalin at 2.0 kg a.i/ha and two hoe-weeding at 3 and 6WAS. In 2012 and combined mean three hoe-weeding gave higher calyx weight/ plant than all the other treatments. This was followed by treatments with pendimethalin and metolachlor at the two available rates and two hoe-weeding at 3 and 6WAS which in turn was higher than the rest of the treatments. In the two years and the combined means in this location, the weedy check consistently gave the least calyx yield, which was lower than all the herbicides and hoe-weeded treatments.

In 2011 at Afaka, three hoe-weeding gave significantly higher calyx weight/plant than all other treatments. This was followed by pedimethalin at the two given rates and metolachlor at 1.5 kg a.i/ha which was higher than the rest of the treatments. In 2012, three hoe-weeding at 3, 6 and 9WAS, metolachlor and pendimethalin each at 1.5 kg a.i/ha resulted in higher calyx weight/plant than all the other treatment except pendimethalin at 2.0 kg a.i/ha and two-hoe-weeding at 3 and 6WAS which gave higher calyx weight than the rest of the treatments. In the combined mean, three hoe-weeding gave higher calyx weight than the rest of the treatments. Followed by treatment with metolachlor at 1.5 kg a.i/ha and pendimethalin at the two given rates which was in turn higher than the rest of the treatments. The two levels of diuron gave least number of calyx in 2011 and the combined mean, while the weedy check was the least in 2012.

4.5.3 Calyx yield

The effects of weed control methods on calyx yield of roselle during wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka is presented in Table 33. At Samaru in 2011, pendimethalin at 1.5 kg a.i /ha and three hoe-weeding at 3, 6 and 9WAS gave higher calyx yield than all the other treatments, followed by metolachlor at 1.5 kg a.i /ha and pendimethalin at 2.0 kg a.i/ha which in turn were higher than the other treatments, except butachlor at two given rates. In 2012 and the combined data three hoe-weeding gave higher calyx yield than all the other treatments, followed by pendimethalin at 1.5 and 2.0 kg a.i/ha, which in turn was higher than the remaining treatments. In the two years and the

Table 31: Effects of Weed Control Methods on Number of Calyx/plant of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka..

		Number of calyx/plant					
		Samaru			Afaka		
Treatment	Rates(kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	96.33g	204.00f	150.66e	11.00d	13.67cde	12.34d
Oxadiazon	2.0	85.200h	205.00f	145.10ef	9.00e	12.33def	10.67de
Diuron	2.0	72.12i	210.00f	141.05f	0.10g	13.67cde	6.89f
Diuron	2.5	68.00i	196.00g	132.00g	0.10g	10.67f	5.39f
Metolachlor	1.5	177.33c	329.00b	253.17bc	13.33c	18.33b	15.83c
Metolachlor	2.0	167.33d	322.00c	244.67c	11.33d	15.00c	13.17d
Butachlor	1.5	164.33d	300.00e	232.17d	12.33cd	14.33cd	13.33d
Butachlor	2.0	155.67e	313.00d	234.34d	9.67e	11.67ef	10.67de
Pendimethalin	1.5	178.00c	327.00b	252.50bc	15.33b	19.67b	17.50b
Pendimethalin	2.0	188.00b	334.50b	261.25b	13.00c	18.33b	15.67c
HW @ 4WAS	-	103.00f	104.00h	103.50h	9.00e	12.00def	10.50de
HW @ 3&6WAS	-	179.00c	320.00c	249.50c	11.33d	20.33b	15.83c
HW @ 3 ,6& 9WAS	-	200.67a	387.00a	293.84a	19.00a	25.00a	22.00a
Weedy check	-	56.00j	100.00h	78.00i	5.00f	7.00g	6.00f
SE±		1.186	2.326	1.756	0.259	0.648	0.454

Means followed by the same letter (s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

Table 32: Effects of Weed Control Methods on Calyx Weight/plant (g) of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka

		Calyx weight/plant (g)					
		Samaru			Afaka		
Treatment	Rates(kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	642.00d	1158.62e	900.31d	45.00cd	52.67c	48.84c
Oxadiazon	2.0	620.00e	1159.68e	889.84de	39.33e	47.33e	43.33e
Diuron	2.0	613.00e	1162.51e	887.76e	0.10g	48.00de	24.05g
Diuron	2.5	550.00f	864.51f	707.26ff	0.10g	45.00f	22.55g
Metolachlor	1.5	835.33bc	2038.42b	1436.88b	49.67b	57.00a	53.34b
Metolachlor	2.0	832.32bc	2034.12b	1433.22b	46.33c	54.00bc	50.17c
Butachlor	1.5	830.00bc	2016.49c	1423.25c	45.33cd	52.33c	48.83c
Butachlor	2.0	825.33c	2010.14d	1417.74c	44.33cd	49.67d	47.00d
Pendimethalin	1.5	844.00b	2038.17b	1441.09b	51.33b	57.00a	54.17b
Pendimethalin	2.0	834.67bc	2039.24b	1436.96b	51.33b	55.67ab	53.50b
HW @ 4WAS	-	475.33g	768.41g	621.87g	42.00de	48.00de	45.00de
HW @ 3&6WAS	-	839.33bc	2036.42b	1437.88b	45.00cd	55.33ab	50.17c
HW @ 3 ,6& 9WAS	-	868.00a	2098.28a	1483.19a	56.67a	57.00a	56.84a
Weedy check	-	375.00h	761.27g	568.14h	29.33f	35.00g	32.17f
SE±		2.745	3.175	2.960	0.627	0.425	0.526

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

combined data at this location, the weedy check consistently gave the least calyx yield, which was lower than all the herbicides and hoe-weeded treatments, except hoe-weeding at 4WAS in 2012.

At Afaka in the two years and the combined means, hoe-weeding at 3, 6 and 9WAS gave higher calyx yield than all the other weed control treatments. This was followed by treatment with pendimethalin in both years and combined means and metolachlor at 1.5 kg a.i /ha in 2012, which in turn gave higher yields than the remaining hoe-weeded and herbicide treatments. In the combined, diuron at both rates gave the least. The weedy check consistently resulted in the least calyx yield, which in each case was lower than all the other treatments in question.

4.5.4 Number of seeds/capsule

The effects of weed control methods on number of seeds/capsule of roselle during wet seasons of 2011and 2012 and the combined data at Samaru and Afaka is shown in Table 34. In 2011 at Samaru, three hoe-weedings at 3, 6 and 9WAS significantly gave more number of seeds/capsule than all the other weed control treatments except metolachlor at 1.5 kg a.i /ha. This was followed by pendimethalin at 1.5 and 2.0 kg a.i /ha, each of which in turn gave more number of seeds/capsule than the rest of the treatments. In the same location 2012, three hoe-weeding significantly gave more number of seeds/capsule than all the other treatments. Followed by pendimethalin and metolachlor at the two available rates, butachlor at 1.5 kg a.i /ha and two hoe-weeding at 3 and 6 WAS, each of which was gave more number of seed /capule than the rest of the treatments. In the combined data, three hoe-weeding at 3, 6 and 9WAS resulted in significantlty more number of seeds /capsule than all the other reatments. The least number of seeds/capsule was consistently produced by diuron at 2.5 kg a.i/ha.

Table 33: Effects of Weed Control Methods on Calyx yield/ha (kg) of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

		Calyx yield/ha (kg)					
		Samaru			Afaka		
Treatment	Rates(kga. i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	825.10d	1459.00e	1142.05e	617.23d	960.00e	788.67f
Oxadiazon	2.0	725.12e	940.00h	862.56j	537.80e	840.00g	688.90g
Diuron	2.0	628.13f	1355.00f	991.57f	0.10h	696.70h	348.35j
Diuron	2.5	424.70g	1343.00f	883.85h	0.10h	693.10h	346.57j
Metolachlor	1.5	1479.10b	1535.00d	15072.55c	727.20c	1078.33b	902.77c
Metolachlor	2.0	1467.30bc	1584.00c	15263.15c	666.10d	1031.67c	848.89d
Butachlor	1.5	1469.70bc	1566.00c	15180.85c	647.80d	1008.33d	828.07e
Butachlor	2.0	1458.20bc	1574.00c	15165.60c	620.00d	942.67e	781.34f
Pendimethalin	1.5	1551.00a	1691.00b	16216.00b	799.40b	1075.00b	937.20b
Pendimethalin	2.0	1532.60b	1695.00b	16139.30b	784.70b	1064.33b	924.52b
HW @ 4WAS	-	529.60.60g	1318.00g	923.80g	411.10f	865.33f	638.22h
HW @ 3&6WAS	-	1437.10c	1553.00d	1495.60d	747.80bc	1027.77cd	887.79c
HW @ 3 ,6& 9WAS	-	1556.90a	1753.00a	1655.45a	864.10a	1125.00a	994.55a
Weedy check	-	4252.20g	1323.00g	874.60i	351.93f	607.67i	479.79i
SE±		6.029	7.244	6.637	10.749	3.869	7.309

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Means followed by the same letter (s) within a column are not significantly different at P ≤ 0.05 level of probability using DMRT.

Table 34: Effects of Weed Control Methods on Number of Seeds/capsule of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

		Number of seeds/capsule					
		Samaru			Afaka		
Treatment	Rates (kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	31.33de	29.00d	30.17d	13.33e	18.00cd	15.67e
Oxadiazon	2.0	29.67f	27.00e	28.34e	12.00e	15.67f	13.84f
Diuron	2.0	22.00g	27.67e	24.84f	0.10f	16.00ef	8.05h
Diuron	2.5	18.33h	21.00f	19.67g	0.10f	15.00fg	7.55h
Metolachlor	1.5	34.00ab	33.33b	33.67b	18.00b	21.00b	19.50b
Metolachlor	2.0	32.33cd	32.00b	32.17c	15.67d	17.67de	16.67d
Butachlor	1.5	33.00bc	32.33b	32.67bc	17.67bc	19.33bcd	18.50bc
Butachlor	2.0	30.67ef	30.67c	30.67d	16.00cd	19.00cd	17.50c
Pendimethalin	1.5	33.33b	32.33b	32.83bc	16.00cd	21.00b	18.50bc
Pendimethalin	2.0	33.33b	33.00b	33.17b	17.00bcd	19.67bc	18.34bc
HW @ 4WAS	-	30.00ef	27.33e	28.67d	13.33e	16.00ef	14.67f
HW @ 3&6WAS	-	32.67bcd	32.67b	32.67bc	17.67bc	21.00b	19.34b
HW at 3 ,6,&9WAS	-	35.00a	35.00a	35.00a	21.00a	26.00a	23.50a
Weedy check	-	31.00de	29.00d	30.00d	11.67e	13.67g	12.67g
SE$\pm$		0.264	0.247	0.255	0.341	0.337	0.339

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

In 2011 at Afaka, three hoe-weeding at 3, 6 and 9WAS significantly gave more number of seeds /capsule than all the other treatments. This wasfollowed by metolachlor at 1.5 kg a.i/ha which in turn gave more number of seeds/capsule than the rest of the treatments.In 2012 in the same location, more number of seeds/ capsule was produced by three hoe-weedings, this was followed by two hoe-weeding at 3 and 6WAS and metolachlor at 1.5 kg a.i /ha, each of this gave more number of seeds /capsule than the rest of the treatments. In the combined data, three hoe-weedings gave more number of seeds /capsule than all the other treatments. The least nimber of seeds / capsule was consistently produced by diuron at 2.5 kg a.i/ha.

4.5.5 Weight of seeds/capsule (g)

Table 35 shows the effects of weed control methods on weight of seeds/capsule of roselle during wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka.In 2011 and 2012 and the combined data at Samaru, higher weight of seeds/capsule was by three hoe-weedings at 3,6and 9WAS, compared to all other treatments, except the two available rates, each of metolachlor and pendimethalin in 2011. Diuron at 2.5 kg a.i/ha consistently gave the least seed weight/capsule in both years and combined data.

In 2011, 2012 and combined data at Afaka, three hoe-weedings at 3, 6 and 9WAS gave higher seeds weight/ capsule than all the other treatments. The least weight of seeds /capsule was by diuron at two given rates in 2011 and combined and weedy check in 2012.

Table 35: Effects of Weed Control Methods on Weight of Seeds/capsule (g) of Roselle during Wet Seasons of 2011, 2012 and Combined.at Samaru and Afaka.

		Weight of seeds/capsule(g)					
		Samaru			Afaka		
Treatment	Rates (kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	1.15c	1.00d	1.08c	0.43c	0.52d	0.48d
Oxadiazon	2.0	1.00d	1.00d	1.00c	0.40c	0.47e	0.44e
Diuron	2.0	0.57e	1.00d	0.79d	0.10e	0.49e	0.30g
Diuron	2.5	0.51e	0.75e	0.63e	0.10e	0.47e	0.29g
Metolachlor	1.5	1.29ab	1.27b	1.28b	0.53b	0.57b	0.55b
Metolachlor	2.0	1.28ab	1.27b	1.28b	0.50b	0.53cd	0.52c
Butachlor	1.5	1.26b	1.24c	1.25b	0.53b	0.54cd	0.54b
Butachlor	2.0	1.24b	1.24c	1.24b	0.51b	0.54cd	0.53c
Pendimethalin	1.5	1.26ab	1.24c	1.28b	0.51b	0.58b	0.55b
Pendimethalin	2.0	1.27ab	1.26b	1.25b	0.51b	0.56bc	0.54b
HW @ 4WAS	-	1.11c	1.00d	1.06c	0.40c	0.48e	0.44e
HW @ 3&6WAS	-	1.25b	1.25bc	1.25b	0.53b	0.58b	0.56b
HW @ 3 ,6& 9WAS	-	1.35a	1.35a	1.35a	0.59a	0.64a	0.62a
Weedy check	-	1.15e	1.00d	1.08c	0.36d	0.37f	0.37f
SE$\pm$		0.015	0.028	0.022	0.009	0.005	0.007

Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

4.5.6 100 seed weight

Table 36 shows the effects of weed control methods on 100 seed weight of roselle during the wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka. In 2011 and 2012 and the combined data at Samaru, three hoe-weedings resulted in greater 100seed weight than all the other weed control treatments. In 2011, pendimethalin at 1.5 kg a.i /ha gave greater 100 seed weight than the other herbicide treatments and one and two hoe-weedings at 4 and 3and6WAS. This was followed by two hoe-weedinsgs at 3and 6WAS which in turn gave greater 100 seed weight than the remaining treatments. In 2012, apart from the highest value, greater 100 seed weight was by pendimethalin at 1.5 kg a.i /ha, followed by metolachlor at 1.5 kg a.i /ha and two hoe-weeding at 3 and 6WAS each gave similar and greater 100 seed weight than the remaining treatments. In the combined data, pendimethalin at 1.5 kg a.i /ha gave greater 100 seed weight than the other herbicide treatments and one and two hoe weeding. This was followed by metolachlor, butachlor, each at the two given rates and two hoe-weeding at 3 and 6 WAS which in turn higher than the remaining treatments. The least 100 seed weight was by diuron at 2.5 kg a.i /ha in both years and the combined data.

At Afaka, the three hoe-weedings at 3,6 and 9WAS in the two years and combined data, two hoe-weeding at 3 and 6WAS and pendimethalin at 1.5kg a.i /ha in 2012 resulted in greater 100 seed weight than all the other weed control treatments. The least seed weight was by oxadiazon at 2.0kg a.i /ha and the two levels of diuron in 2011 and combined data and the weedy check in 2012.

Table 36: Effects of Weed Control Methods on 100 Seed Weight (g) of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

		100 seed weight (g)					
		Samaru			Afaka		
Treatment	Rates (kg a.i/ha)	2011	2012	Combined	2011	2012	Combined
Oxadiazon	1.5	2.56f	2.58g	2.57e	2.23b	2.47b	2.35b
Oxadiazon	2.0	2.53g	2.55h	2.54fg	2.21b	2.40bc	2.31bc
Diuron	2.0	2.52g	2.51i	2.52g	0.10d	2.45b	1.28d
Diuron	2.5	2.47h	2.47j	2.47h	0.10d	2.42b	1.26d
Metolachlor	1.5	2.69cd	2.71c	2.70c	2.26b	2.49b	2.38b
Metolachlor	2.0	2.68d	2.69d	2.69c	2.20bc	2.50ab	2.35b
Butachlor	1.5	2.68d	2.70cd	2.69c	2.23b	2.48b	2.36b
Butachlor	2.0	2.68d	2.67e	2.69c	2.20bc	2.48b	2.34b
Pendimethalin	1.5	2.78b	2.79b	2.79b	2.26b	2.51a	2.39b
Pendimethalin	2.0	2.64e	2.64f	2.64d	2.21b	2.48b	2.35b
HW @ 4WAS	-	2.43i	2.44k	2.44i	2.13c	2.37c	2.25c
HW @ 3, & 6 WAS	-	2.71c	2.71c	2.71c	2.23b	2.52a	2.38b
HW @ 3 ,6 & 9WAS	-	2.82a	2.86a	2.84a	2.42a	2.61a	2.52a
Weedy Check	-	2.56f	2.58g	2.57e	2.17c	2.33c	2.25c
SE$\pm$		0.004	0.003	0.004	0.020	0.040	0.030

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

4.6 Correlations

Matrix of correlation between combined calyx yield of roselle, some growth and yield characters and weed parameters during wet seasons of 2011 and 2012 at Samaru and faka are presented in Tables 37 and 38. At Samaru (Table 37), calyx yield was highly and positively correlated with weed control index, plant height, number of l eaves/plant, number of primary branches, stem girth, each at 9WAS, number of calyx/plant and calyx weight/plant.

Weed dry weight was negatively correlated with number of leaves/plant and also highly and negatively correlated with weed control index and plant height. Weed control index was positively correlated with number of leaves and highly and also positively correlated with plant height. Plant height was positivelycorrelated with stem girth and number of calyx/plant and also highly and positively correlated with number of leaves, number of primary and secondary branches/plant. The number of leaves/plant was highly and positively correlated with numbers of primary and secondary branches, number of calyx/plant and calyx weight/plant.The number of primary branches were highly and positively correlated with number of secondary branches, number of calyx/plant and calyx weight/plant. Number of secondary branches was highly and positively correlated with calyx number/plant and calyx weight/plant.The correlation between number of calyx and weight of calyx/plant was strong and positive.

At Afaka (Table 38), calyx yield was highly and positively correlated with plant height, number of leaves; number of primary and secondary branches/plant, stems girth, each at 9WAS, as well as calyx number and weight/plant. Weed dry weight was negatively correlated with number of primary branches/plant and also highly and negatively correlated with weed control index and number of calyx/plant. Weed control index was positively

Table 37: Matrix of correlation coefficients between combined calyx yield of roselle, some growth and yield characters and weed parameters during 2011 and 2012 wet seasons at Samaru.

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.047^{NS}	1.000								
3	0.052^{NS}	-0.890**	1.000							
4	0.626**	-0.659**	0.580**	1.000						
5	0.676**	-0.361*	0.366*	0.695**	1.000					
6	0.645**	-0.223^{NS}	0.277^{NS}	0.631**	0.732**	1.000				
7	0.134^{NS}	-0.079^{NS}	-0.079^{NS}	0.445**	0.672**	0.518**	1.000			
8	0.824**	-0.268^{NS}	-0.268^{NS}	0.358*	0.179^{NS}	0.210^{NS}	-0.048^{NS}	1.000		
9	0.867**	-0.258^{NS}	-0.125^{NS}	0.359*	0.652**	0.491**	0.933**	0.106^{NS}	1.000	
10	0.780**	-0.220^{NS}	0.126^{NS}	-0.044^{NS}	0.0.619**	0.439**	0.793**	0.238^{NS}	0.867**	1.000

Df=40, r at 5% =0. 304, r at 1% 0. 393 * Significant correlation at 5% level of significance ** Highly significant correlation at 1% level of significance NS Not significant

1= Calyx yield/hectare (kg) 2= weed dry weight (9WAS), 3= Weed control index (9WAS), 4= Plant height (9WAS), 5= Number of leaves (9WAS), 6=Number of primary branches/plant (9WAS) 7=Number of secondary branches/plant (9WAS) 8= Stem girth (9WAS) 9= Number of calyx/plant 10= Calyx weight/plant.

Table 38: Matrix of correlation coefficients between combined calyx yield of roselle, some growth and yield characters and weed parameters during 2011 and 2012 wet seasons at Afaka.

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.323 NS	1.000								
3	0.328 NS	- 0.999**	1.000							
4	0.884**	-0.215 NS	0.218 NS	1.000						
5	0.847**	-0.212 NS	0.218 NS	0.857**	1.000					
6	0.860**	-0.337*	0.342*	0.809**	0.798**	1.000				
7	0.882**	-0.248 NS	0.254 NS	0.661**	0.787**	0.707**	1.000			
8	0.948**	-0.190 NS	0.190 NS	0.875**	0.853**	0.884**	0.882**	1.000		
9	0.898**	-0.507**	0.510**	0.779**	0.798**	0.751**	0.768**	0.825**	1.000	
10	0.883**	-0.289 NS	0.292 NS	0.959**	0.846**	0.808**	0.692**	0.883**	0.877**	1.000

Df=40, r at 5% =0. 304, r at 1% 0. 393 * Significant correlation at 5% level of significance ** Highly significant correlation at 1% level of significance NS Not significant

1= Calyx yield/hectare (kg) 2= weed dry weight (9WAS), 3= Weed control index (9WAS), 4= Plant height (9WAS), 5= Number of leaves (9WAS), 6=Number of primary branches/plant (9WAS) 7=Number of secondary branches/plant (9WAS) 8= Stem girth (9WAS) 9= Number of calyx/plant 10= Calyx weight/plant.

correlated with number of primary branches and highly and positively correlated with number of calyx/plant. Plant height was highly and positively correlated with number of leaves, number of primary and secondary branches/plant, stem girth/plant, number and weight of calyx/plant.The number of leaves/plant was highly and positively correlated with number of primary and secondary branches/plant, stem girth/plant, number and weight of calyx/plant. The number of primary branches/plant was highly and positively correlatedwith number of secondary branches/plant; stem girth/plant, number and weight of calyx/plant. Number of secondary branches/plant was strongly and positively correlated with stem girth /plant, number and weight of calyx/plant. The stem girth/plant was also highly and positively correlated to number and weight of calyx/plant. The correlation between number of calyx and weight of calyx/plant was also strong and positive.

EXPERIMENT II Weed interference

4.7 Weed Parameters

4.7.1 Weed cover score

Tables 39 and 40 show the effects of period of weed interference on weed cover score at 3, 6, 9 and 12WAS of roselle during the wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011at Samaru and at 3WAS (Table 39), plots initially kept weed-free for 3WAS and beyond resulted in similar and lower weed cover score than those left weed infested for the respective periods. At this location, at 6WAS, plots initially kept weed-free for 3WAS and beyond and that initially left infested for 3WAS only, resulted in similar and lower weed cover score than those left weed-infested for 6WAS and beyond. At 9WAS, plots initially kept weed-free for 6WAS and beyond and those left weed-infested for 3 and 6WAS resulted in similar and lower weed cover score than those initially left weed-infested for 9WAS and until harvest, as well as the plots kept weed free for 3WAS only, which in turn recorded lower weed cover score than the highest by plots left weed-infested for 12WAS and beyond. At 12WAS, plots kept weed free for 9WAS and beyond, and those left weed infested for 3- 9WAS gave lower weed cover score than plot kept weed-free for 3 and 6WAS and those left infested for 12WAS and beyond. Plots kept weed free for 3WAS also gave lower weed score than the highest score by those infested for up to 12WAS and beyond.

At Afaka, similar trend was observed. At 3WAS, plots initially kept weed-free for 3WAS and beyond gave similar and lower weed cover score than those left weed infested for 3WAS and beyond. However, the plots initially left weed infested for 3WAS, gave lower weed score than that left weed infested for 9WAS. At 6WAS, the plots that were initially kept weed-free for 3WAS and beyond and that initially left infested for 3WAS only, gave lower weed score than those infested for 6WAS and beyond.The plots kept weed free for 3WAS was however recorded higher weed score than those kept weed-free for longer periods as well as that left infested for 3WAS only. Plots left weed infested until harvest gave higher weed cover score than all the other treatments. At 9WAS in this location, plots that were initially kept weed-free for 9WAS and beyond and those left weed infested for 3and6 WAS gave lower weed score than all the other treatments. In turn, plots kept weed-free for 3 and6 WAS gave lower weed score than those left weed infested for 12WAS and beyond. At 12WAS, plots kept weed free for 6WAS and beyond and those weed-infested for 3-9WAS resulted in lower weed cover score than plots left weed infested until harvest. However, the weed cover scores by plots initially infested for 12WAS and those initially kept weed free for 3WAS were similar to the highest by the weedy check (infested until harvest) and plots kept weed free for 9WAS.

Table 39: Effect of Period of Weed Interference on Weed Cover Score of Roselle during Wet Season of 2011, at Samaru and Afaka.

	Weed cover score							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	3.00ab	1.00c	1.00d	1.00d	2.33b	1.00e	1.00d	1.00d
Weed Infested for 6WAS	2.67b	3.67b	1.00d	1.00d	3.00ab	3.67c	1.00d	1.00d
Weed Infested for 9WAS	3.00ab	4.00b	6.67b	1.00d	3.67a	4.00bc	7.00a	1.00d
Weed Infested for 12WAS	3.00ab	4.00b	7.00ab	8.00b	3.00ab	4.33b	7.33a	5.67abc
Weed Infested until harvest	3.33a	5.67a	7.67a	9.00a	3.00ab	5.00a	7.67a	9.00a
Weed Free for 3 WAS	1.00c	1.33c	3.67c	7.33b	1.00c	2.00d	4.00b	6.33ab
Weed Free for 6 WAS	1.00c	1.00c	1.33d	2.33c	1.00c	1.00e	2.00c	2.67cd
Weed Free for 9 WAS	1.00c	1.00c	1.00d	1.00d	1.00c	1.00e	1.00d	3.00bcd
Weed Free for 12 WAS	1.00c	1.00c	1.00d	1.00d	1.00c	1.00e	1.00d	1.00d
Weed Free until harvest	1.00c	1.00c	1.00d	1.00d	1.33c	1.00e	1.00d	1.00d
SE$\pm$	0.084	0.109	0.145	0.138	0.156	0.091	0.125	0.778

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

In 2012 at Samaru when sampled at 3WAS, (Table 40) the same trend was observe as in Samaru 2011. At 6WAS, plots initially kept weed free for 3WAS and beyond and those initially left weed infested for 3WAS only gave lower weed cover score than those left weed infested for 6WAS and beyond. At 9WAS, plots initially kept weed free for 6WAS and beyond and those that left infested for 3and6WAS resulted in similar and lower weed cover score than those initially left weed infested for 9WAS and beyond, as well as those plot kept weed free for 3WAS only, which in turn gave lower weed cover score than the highest by the plots left weed infestedfor 9WAS and until harvest. At 12WAS, plots kept weed free for 6WAS and beyond, and those that left weed infested for 3-9WAS gave similar and lower weed cover score than those plots kept weed free for 3WAS and those left weed infested for 12 WAS and beyond. Plots kept weed free for 3WAS also gave lower weed score than the highest score by those infested for up to 12WAS and beyond.

At Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond resulted in similar and lower weed cover score than those left weed infested for 3WAS and beyond. In turn, plots initially left weed infested for 3WAS gave lower weed score than those left infested for 6WAS and beyond. At 6WAS, the plots initially kept weed-free for 3WAS and beyond and those that initially left weed infested for 3WAS only resulted in similar and lower weed cover scores than those left infested for 6WAS and beyond. Plots left weed infested for 6WAS and until harvest were similar to the highest by those left weed infested until harvest. At 9WAS, plots that were initially kept weed free for 6WAS and beyond and those initially left weed infested for 3and6WAS resulted in similar and lower weed cover score than all the other treatments. In turn, plots kept weed free for 3WAS gave lower weed score than those left infested for 9WAS and beyond. At 12WAS, plots kept weed free for 6WAS and beyond and those left weed infested for 3-9WAS resulted in lower weed cover

Table 40: Effect of Period of Weed Interference on Weed Cover Score of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Weed cover score							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	2.33ab	1.00c	1.33c	1.33d	1.67bc	1.00b	1.00c	1.33d
Weed Infested for 6WAS	2.00abc	3.67a	1.00c	1.33d	2.33ab	4.33a	1.00c	1.00d
Weed Infested for 9WAS	2.67a	4.33a	7.00a	1.00d	2.33ab	4.33a	8.00a	1.00d
Weed Infested for12WAS	2.33ab	4.33a	6.67a	8.67a	2.33ab	4.33a	7.67a	8.33a
Weed Infested until harvest	2.00abc	4.33a	6.67a	9.00a	2.67a	4.67a	7.67a	9.00a
Weed Free for week 3WAS	1.00d	2.00b	5.67b	7.67b	1.00c	1.33b	3.00b	6.00b
Weed Free for week 6WAS	1.33cd	1.00c	1.33c	3.00c	1.00c	1.00b	1.33c	3.00c
Weed Free for week 9WAS	1.33cd	1.00c	1.00c	1.00d	1.00c	1.00b	1.00c	1.67d
Weed Free for week 12WAS	1.67bcd	1.00c	1.00c	1.00d	1.00c	1.00b	1.00c	1.00d
Weed Free until harvest	1.00d	1.00c	1.00c	1.00d	1.00c	1.00b	1.00c	1.00d
SE$\pm$	0.139	0.122	0.123	0.166	0.133	0.139	0.109	0.139

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

score than plots left weed infested for 12WAS and beyond and those kept weed free for 3WAS. The plots initially left weed infested for 12WAS and beyond gave similar weed score and highest among the treatments.

4.7.2 Weed dry weight (g)

The effect of period of weed interference on weed dry weight at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 41 and 42. In 2011 at Samaru (Table 41), period of weed interference had significant effect on weed dry weight. At 3WAS, plots initially kept weed free for 3WAS and beyond resulted in lower weed dry weight than those left weed infested for the corresponding periods. At this location and at 6WAS, plots initially kept weed free for 3WAS and beyond and that initially left weed infested for 3WAS only gave lower weed dry weight than those left weed infested for 6WAS and beyond. At 9WAS, plots initially kept weed free for 9WAS and beyond and those left weed infested for 3 and 6WAS resulted in lower weed dry weight than those kept weed free for 3 and 6WAS and those left weed infested for 9WAS and until harvest.At 12WAS, plots kept weed-free for 6WAS and beyond, and those that left weed infested for 3-9WAS gave lower weed dry matter than those kept weed-free for 3WAS only and those that left weed infested for 12WAS and beyond. Plots kept weed-free for 3WAS only also gave lower weed dry weight than the highest dry weight by those left infested until harvest.

At Afaka, similar trend was observed as in Samaru in 2011. At 3WAS, plots initially kept weed-free for 3WAS and beyond resulted in lower weed dry weight than those left weed infested for 3WAS and beyond. At 6WAS, the plots initially kept weed-free for 3WAS and beyond and those initially left weed infested for 3WAS only gave similar and lower weed dry weight than those left infested for 6WAS and beyond. The plots left weed infested for

Table 41:Effect of Period of Weed Interference on Weed Dry Weight (g) of Roselle during Wet Season of 2011, at Samaru and Afaka.

	Weed dry weight (g)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	68.11c	4.00e	4.11f	4.00g	14.55d	4.81c	3.00e	3.00e
Weed Infested for 6WAS	67.12d	90.07c	4.10f	4.07fg	15.38c	31.43b	3.00e	3.00e
Weed Infested for 9WAS	68.14c	90.12c	140.12c	4.12f	15.36c	32.97b	75.33b	3.00e
Weed Infested for 12WAS	70.12b	91.12b	142.14b	170.13b	16.28b	32.81b	75.67b	120.00b
Weed Infested until harvest	78.12a	103.88a	178.00a	220.13a	20.75a	45.20a	90.00a	140.00a
Weed Free for 3 WAS	4.07e	7.12d	138.74cd	162.11c	4.21e	5.23c	71.00c	115.00c
Weed Free for 6 WAS	4.10e	4.00e	7.13e	15.12d	4.20e	4.21c	5.00d	35.67d
Weed Free for 9 WAS	4.10e	4.10e	4.00f	5.07e	3.91e	4.21c	3.00e	3.00e
Weed Free for 12 WAS	4.10e	4.10e	4.00f	4.03g	3.90e	4.62c	3.00e	3.00e
Weed Free until harvest	4.00f	4.00e	4.00f	4.07f	3.30f	4.31c	3.00e	3.00e
SE$\pm$	0.008	0.061	0.057	0.012	0.091	0.335	0.609	0.609

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

6-12WAS were similar and gave lower weed dry weight than those left weed infested until harvest. Plots left infested until harvest gave highest weed dry weight among the treatments. At 9WAS, plots that were initially kept weed free for 9WAS and beyond an those left infested for 3 and 6WAS only gave similar and lower weed dry weight than those kept weed free for 3and 6WAS and those left infested for 9WAS and longer. In turn, plots that were kept weed free for 6WAS gave lower weed dry weight than those that left infested for 9WAS and beyond, and those plots kept weed free for 3WAS only. Plots kept weed free for 3WAS resulted in lower weed dry weight than those left infested for 9WAS and beyond. The dry weight by those left infested for 9 and 12WAS were similar to the highest by unweeded control. At 12WAS, plots kept weed-free for 9WAS and until harvest and those left infested for 3-9WAS gave lower weed dry weight than those left infested for 12WAS and until harvest and those kept weed free for 3and6WAS. However, the weed dry weight by the plots that was initially kept weed free for 6WAS was lower than those left infested for 12WAS and beyond and those that kept weed free for 3WAS. In turn, the weed dry weight by plots kept weed free for 3WAS was lower than by those that left infested for 12WAS and until harvest. Plots left weed infested for 12WAS gave lower weed dry weight than those left infested until harvest, being the highest in the trial.

In 2012 at Samaru and at 3WAS (Table 42), plots initially kept weed free for 3WAS and beyond resulted in similar and lower weed dry weight than those left weed infested for the respective periods. At 6WAS, plots initially kept weed-free for 3WAS and beyond and those initially left weed infested for 3WAS only gave lower weed dry weight than those left weed infested for 6WAS and beyond.

At Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond gave similar and lower weed dry weight than those left infested for 3WAS and beyond. At 6WAS, the

Table 42: Effect of Period of Weed Interference on Weed Dry Weight (g) of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Weed dry weight (g)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed infested for 3WAS	72.67b	4.07f	4.07e	4.00f	27.00c	4.00f	3.91f	4.07e
Weed Infested for 6WAS	70.33d	102.00d	4.00e	4.00f	26.33d	59.00d	3.90f	4.07e
Weed Infested for 9WAS	71.33c	107.00b	160.33b	4.00f	27.00c	60.00c	110.00c	4.00e
Weed Infested for 12WAS	71.33c	105.00c	160.67b	210.00b	27.67b	62.00b	112.00b	167.37b
Weed Infested until harvest	82.12a	120.33a	192.33a	233.67a	35.00a	82.00a	127.67a	184.33a
Weed Free for 3WAS	4.03e	8.00e	152.67c	178.33c	4.03e	9.33e	82.00d	130.00c
Weed Free for 6WAS	4.00e	4.00f	9.67d	42.00d	4.00e	4.00f	7.20e	40.67d
Weed Free for 9WAS	4.00e	4.00f	4.00e	12.00e	4.00e	4.10f	3.97f	4.07e
Weed Free for 12WAS	4.03e	4.00f	4.00e	4.10f	4.00e	3.97f	3.84f	4.02e
Weed Free until harvest	4.03e	4.00f	4.00e	4.10f	4.00e	4.00f	3.91f	3.98e
SE$\pm$	0.109	0.061	0.212	0.085	0.084	0.061	0.062	0.145

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

plots that were initially kept weed-free for 6WAS and beyond and those initially left weed infested for 3WAS only, gave lower weed dry weight than those left infested for 6WAS and beyond and those kept weed free for 3WAS only.The plots initially kept weed free for 3WAS only however recorded lower dry weight than those left infested for 6WAS and beyond. Plots left infested until harvest gave the highest weed dry weight in the trial. At 9WAS, plots initially kept weed-free for 9WAS and beyond and those left infested for 3 and 6WAS only gave similar and lower weed dry weight than all the other treatments. In turns, plots kept weed-free for 6WAS gave lower weed dry weight than those kept weed free for 3WAS and those left infested for 9WAS and beyond. At 12WAS, plots kept weed free for 9WAS and longer and those left infested for 3-9WAS resulted in similar and lower weed dry weight than plots left infested for 12WAS and beyond and those kept weed free for 3 and 6WAS only. However, the dry weight by plots that were initially left weed free for 6WAS was lower than those kept weed free for 3WAS and those initially left infested for 12WAS and beyond. The weedy check gave the highest weed dry weight value.

4.7.3 Weed control index

The effects of period of weed interference on weed control index at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 43 and 44. At 3WAS in 2011 at Samaru (Table 43), plots initially kept weed free for 3WAS and beyond resulted in higher weed control index (WCI) than those left weed infested for the respective periods. At 6WAS, plots initially kept weed free for 3WAS and beyond and those initially left weed infested for 3WAS only gave higher WCI than those that left weed infested for 6WAS and beyond. At 9WAS, plots initially kept weed free for 6WAS and beyond and those left weed infested for 3and 6WAS resulted in higher WCI than those initially left weed infested for 9WAS and until harvest, as well as the plots initially kept weed free for 3WAS, which in turn recorded higher WCI than the lowest by plots left weed infested until harvest. At 12WAS, plots kept weed free for 6WAS and beyond and those left weed infested for 3-9WAS gave higher WCI than plots kept weed free for 3WAS and those left infested for 12WAS and beyond. Plots kept weed free for 3WAS gave higher WCI than the lowest value by those left infested for 12WAS and beyond.

In the same year at Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond gave higher WCI than those left infested for 3WAS and beyond. At 6WAS, the plots that were initially kept weed free for 3WAS and beyond and those that initially left weed infested for 3WAS only gave similar and higher WCI than those left infested for 6WAS and beyond. Plots left weed infested until harvest gave the least WCI in the trial. At 9WAS, plots that were initially kept weed free for 9WAS and beyond and those left infested for 3and 6WAS resulted in similar and higher WCI than all the other treatments. In turn, plots kept weed free for 6WAS gave higher WCI than those left infested for 9WAS and beyond and those kept weed free for 3WAS only. At 12WAS, plots kept weed free for 12WAS and beyond and those left weed infested for 3-9WAS gave higher WCI than plots left infested for longer period and those kept weed free for 3and 6WAS. Similarly, the WCI by plots initially kept weed free for 6WAS was higher than plots left infested for 12WAS and beyond and to those kept weed free for 3WAS. The least result was by the weedy check (infested until harvest).

In 2012 at Samaru and at 3WAS, (Table 44), plots kept initially weed-free for 3WAS and beyond gave similar and higher WCI than those left weed infested for the corresponding periods. At 6WAS, plots initially kept weed free for 6WAS and beyond and those initially left weed infested for 3WAS only, resulted in higher WCI than those left weed infested for 6WAS and beyond and those kept weed free for 3WAS only. At 9WAS, plots initially kept

Table 43: Effect of Period of Weed Interference on Weed Control Index of Roselle during Wet Season of 2011, at Samaru and Afaka

	Weed control index							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed infested for 3WAS	12.00d	96.15a	97.69a	98.18a	29.84d	89.36a	96.67a	97.86a
Weed Infested for 6WAS	14.09c	13.30c	97.69a	98.15ab	25.86e	31.93b	96.67a	97.86a
Weed Infested for 9WAS	12.77d	13.25c	21.28d	98.12b	25.95e	30.02b	16.30d	97.86a
Weed infested for 12WAS	10.24e	12.28d	20.14e	22.17f	21.48f	30.35b	15.93d	14.29e
Weed Infested until harvest	0.00f	0.00e	0.00f	0.00g	0.00g	0.00c	0.00e	0.00f
Weed Free for 3WAS	94.79b	93.14b	22.08c	26,36e	77.08c	88.43a	21.11c	17.86d
Weed Free for 6WAS	94.75b	96.15a	95.99b	93.13d	79.75bc	90.69a	94.44b	72.14c
Weed Free for 9WAS	94.75b	96.06a	97.75a	97.70c	81.10ab	90.66a	96.67a	96.43b
Weed Free for 12WAS	94.75b	96.06a	97.75a	98.16a	81.21ab	89.32a	96.67a	97.86a
Weed Free until harvest	94.87a	96.15a	97.75a	98.15ab	84.09a	90.47a	96.67a	97.86a
SE$\pm$	0.011	0.076	0.031	0.060	0.557	0.736	0.093	0.093

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT

weed free for 6WAS and beyond and those left weed infested for 3 and 6WAS resulted in higher WCI than those initially left weed infested for 9WAS and longer as well as plots kept weed free for 3WAS only which in turn recorded higher WCI than the lowest by plots left weed infested until harvest. At 12WAS, plots kept weed free for 12WAS and beyond and those left weed infested for 3-9WAS gave higher WCI than plots kept weed free for 3 - 9WAS and those left weed infested for 12WAS and beyond.Plots kept weed free for 9WAS also gave higher WCI than those kept weed free for 3and 6WAS and those left infested for 12WAS and until harvest.The plots that were kept weed free for 6WAS gave higher WCI than those left infested for 12WAS and longer and kept weed free for 3WAS only.The least WCI was consistently by the weedy check.

In the same year at Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond resulted in similar and higher WCI than those left infested for 3WAS and beyond. At 6WAS, the plots that were initially kept weed free for 6WAS and beyond and those initially left infested for 3WAS only gave higher WCI than those kept weed free for 3WAS only and those left infested for 6WAS and beyond. Plots kept weed free for 3WAS only also gave higher WCI than those left infested for 6WAS and beyond. At 9WAS, plots that were initially kept weed free for 9WAS and beyond and those left infested for 3and 6WAS gave similar and higher WCI than those that kept weed free for 3and6WAS only and those left weed infested for 9WAS and until harvest. In turn, plots kept weed free for 6WAS gave higher WCI than those left infested for 9WAS and beyond and those kept weed free for 3WAS. At 12WAS, plots kept weed free for 9WAS and beyond and those that left weed infested for 3 and6WAS gave similar and higher WCI than all the other treatments.The WCI by plots initially kept weed free for 6WAS was however, higher than

Table 44: Effect of Period of Weed Interference on Weed Control Index of Roselle during Wet Season of 2012, at Samaru and Afaka

	Weed control index							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	11.97d	96.68a	97.89a	98.26a	25.71b	95.12a	96.93a	97.79a
Weed Infested for 6WAS	14.35b	15.00d	97.92a	98.29a	24.76c	28.20c	96.94a	97.86a
Weed Infested for 9WAS	13.13c	10.83f	16.12d	98.29a	22.86d	22.82d	13.84d	97.83a
Weed Infested for 12WAS	13.54c	12.50e	16.47d	10.13e	20.00e	24.39e	12.27e	9.48d
Weed Infested until harvest	0.00e	0.00g	0.00e	0.00f	0.00f	0.00f	0.00f	0.00e
Weed Free for 3 weeks	95.04a	93.33c	20.62c	23.68d	88.48a	88.62b	35.78c	29.60c
Weed Free for 6 weeks	95.09a	96.67ab	94.97b	82.02c	88.57a	94.12a	94.12b	77.97b
Weed Free for 9 weeks	95.09a	96.67ab	94.92a	94.86b	88.57a	95.00a	96.89a	97.79b
Weed Free for 12 weeks	95.09a	96.64b	97.92a	98.24a	88.57a	95.15a	96.99a	97.82a
Weed Free until harvest	95.09a	96.67ab	97.92a	98.24a	88.57a	95.12a	96.94a	97.84a
SE±	0.136	0.006	0.180	0.033	0.175	0.203	0.067	0.075

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

those kept weed free for 3WAS only and those initially left weed infested for 9WAS and beyond. The least WCI was consistently by weedy check.

4.8 Crop and Growth Characters.

4.8.1 Crop vigour score

The effects of period of weed interference on crop vigor at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 45 and 46. At 3WAS in 2011 at Samaru (Table 45), plots initially kept weed free for 3WAS and beyond and those left weed infested for 6WAS and until harvest gave more vigorous plants than those left infested for 3,9 and12WAS. At 6WAS, plots initially kept weed free for 6WAS and beyond resulted in more vigorous plants than those kept weed free for 3WAS and those left infested for 3WAS and longer. This was followed by plots left weed infested for 3WAS, which in turn gave more vigorous plants than those left infested for 6WAS and beyond and those that kept weed free for 3WAS. At 9WAS, plots initially kept weed free for 6WAS and beyond and those left weed infested for 6WAS resulted in more vigorous plants than those left infested for 3, 9,12WAS and until harvest, as well as those kept weed free for 3WAS only. At 12WAS, plots initially kept weed free for 9WAS and longer and those left infested for 3 and 6WAS resulted in more vigorous plants than those left weed infested for 9WAS and longer and those kept weed free for 3and6WAS. Plots kept weed free for 6WAS gave more vigorous plants than those kept weed free for 3WAS only and those left weed infested for 9WAS and beyond.The crop vigour by plots left weed infested for 9WAS and those kept weed free for 3WAS only resulted in more vigorous plants than those left weed infested for12WAS and beyond.

At Afaka and at 3WAS, plots kept weed free for 3-12WAS and those left weed infested for 6WAS gave more vigorous plants than those left weed infested for 12WAS and beyond.

At 6WAS, plots kept initially weed free for 6WAS and beyond gave more vigorous plants than those left weed infested for 9 and 12WAS. Plots left weed infested for 9WAS gave the least crop vigour. At 9WAS, plots kept weed free for 6WAS and beyond and those left initially weed infested for 3 and 6WAS resulted in similar and more vigorous plants than those kept weed free for 3WAS and those left infested for 9WAS and longer. Plots kept weed free for 3WAS and those left weed infested for 9WAS and until harvest gave more vigorous plants than those left weed infested for 12WAS. At 12WAS, plots kept initially weed free for 6WAS and beyond and those left weed infested for 3and 6WAS resulted in similar and more vigorous plants than those kept weed free for 3WAS and those left infested for 9WAS and longer. Plots left weed infested for 9WAS and those kept weed free for 3WAS resulted in more vigorous plants than those left weed infested for 12WAS and until harvest.

At Samaru in 2012 and at 3WAS (Table 46), plots initially kept weed free for 6-12WAS gave more vigorous plants than plots kept weed free for 3WAS only and those left infested for 3 and6WAS. At 6WAS, plots kept initially weed free for 3WAS and longer gave more vigorous plants than those left weed infested for the corresponding periods. At 9WAS, plots kept initially weed free for 6WAS and beyond and those left weed infested for 6WAS only resulted in more vigorous plants than those kept weed free for 3WAS and those left weed infested for 6WAS and beyond. Plots left weed infested for 3WAS only gave more vigorous plants than those kept weed free for 3WAS and those left weed infested for 9WAS and beyond. At 12WAS, plots kept weed free for 6WAS and beyond and those left weed infested for 3-9WAS gave more vigorous plants than those left weed infested for 12WAS and beyond and those kept weed free for 3WAS only.

Table 45: Effect of Period of Weed interference on Crop Vigor Score of Roselle during Wet Season of 2011, at Samaru and Afaka.

	Crop vigor score*							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	7.00c	8.33b	8.00bc	9.00ab	7.00bcd	8.00bc	9.00a	9.00a
Weed Infested for 6WAS	7.67abc	8.00c	8.67ab	9.00ab	8.00ab	8.00bc	8.33a	8.33a
Weed Infested for 9WAS	7.00c	7.33d	7.67c	7.33c	7.33bc	7.33c	7.33b	7.33b
Weed Infested for 12WAS	7.00c	7.00d	7.33c	6.33d	6.67cd	6.33d	6.33c	5.67c
Weed Infested until harvest	7.67abc	8.00c	8.00bc	6.33d	6.33d	7.67bc	7.00bc	5.67c
Weed Free for 3 WAS	8.33abc	8.00c	7.67c	7.00cd	8.00ab	8.00bc	7.33b	6.67b
Weed Free for 6 WAS	8.33abc	9.00a	9.00a	8.67b	8.67a	9.00a	9.00a	9.00a
Weed Free for 9 WAS	8.67a	8.67ab	9.00a	9.67a	8.00ab	9.00a	8.67a	9.00a
Weed Free for 12 WAS	8.33abc	8.67ab	9.00a	9.33ab	8.00ab	8.33ab	8.67a	9.00a
Weed Free until harvest	8.00abc	9.00a	9.00a	9.00ab	7.67b	9.00a	9.00a	9.00a
SE±	0.238	0.166	0.136	0.152	0.173	0.171	0.148	0.133

WAS: Weeks after sowing.
* Crop vigour score using a scale of 1- 9 where 1 represented completely death plants and 9 represented most vigorous plants.
Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 46: Effect of Period of Weed Interference on Crop Vigor Score of roselle during Wet Season of 2012, at Samaru and Afaka,

	Crop vigor score*							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	4.33bc	7.00bc	8.33b	9.33a	6.00	8.33a	8.67a	8.00abc
Weed Infested for 6WAS	4.33bc	7.00bc	8.67ab	9.00a	5.00	8.00ab	8.33a	8.00abc
Weed Infested for 9WAS	4.67abc	6.33c	7.00c	8.67a	5.33	7.33bc	7.33b	8.33ab
Weed Infested for 12WAS	5.00ab	6.67bc	6.67c	6.33b	6.00	6.67c	8.00ab	7.67abc
Weed Infested until harvest	4.67abc	6.33c	6.67c	6.33b	5.33	6.67c	8.00ab	6.33c
Weed Free for 3WAS	4.33bc	8.67a	7.00c	6.67b	5.00	8.33a	7.33b	7.00bc
Weed Free for 6WAS	5.33ab	8.33a	8.67ab	8.33a	4.33	8.33a	9.00a	9.00a
Weed Free for 9WAS	6.00a	9.00a	9.00a	8.33a	5.00	8.00ab	9.00a	8.67ab
Weed Free for 12WAS	6.00a	8.33a	9.00a	9.00a	5.00	7.33bc	8.67a	9.00a
Weed Free until harvest	4.00bc	8.67a	9.00a	9.00a	5.67	8.00ab	9.00a	8.00abc
SE±	0.235	0.166	0.109	0.194	0.335	0.155	0.173	0.295

WAS: Weeks after sowing.
* Crop vigour score using a scale of 1- 9 where 1 represented completely death plants and 9 represented most vigorous plants.
Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

At Afaka, period of weed interference did not influence crop vigour at 3WAS in 2012. At 6WAS, plots kept weed free for 3, 6 and 9WAS and until harvest and those left weed infested for 3and6WAS resulted in more vigorous plants than those left infested for 12WAS and until harvest. At 9WAS, plots kept weed free for 6WAS and beyond and those left weed infested for 3and 6WAS resulted in more vigorous plants than those left weed infested for 9WAS and those kept weed free for 3WAS. At 12WAS, plots that were kept initially weed free for 6-12WAS and those left weed infested for 9WAS resulted in more vigorous plants than the untreated check.

4.8.2 Stand count at harvest %.

The effects of period of weed interference on number of stands at harvest of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka is presented in Table 47. In 2011 at Samaru, plots initially kept weed free for 3 and 6WAS gave higher percentage stand count at harvest than all the other treatments. This was followed by plots left weed infested for 3-12WAS and those kept weed free for 6WAS which gave higher percentage stand count at harvest than the rest of the treatment. In this year at Afaka, plots initially left weed infested until harvest and those initially kept weed free for 3WAS only gave higher percentage stand count at harvest than all the other treatments. The plots left weed infested for 9 and 12WAS gave higher percentage stand count at harvest than those kept weed free for 6WAS and beyond and those left weed infested for 3 and 6WAS. Plots left weed infested for 3 and 6WAS and those kept weed free for 6WAS gave higher percentage stand count than the rest of the treatment.

Higher percentage stand count on plots left weed infested for 12WAS and until at harvest than all the other treatments. The stand counts by plots kept weed free for 3WAS and those left weed infested for 9WAS were higher than those that kept weed free for 12WAS and

Table 47: Effect of Period of Weed Interference on PercentageStand Count at Harvest of Roselle during Wet Seasons of 2011 and 2012 at Samaru and Afaka

	% Stand count at harvest			
	Samaru		Afaka	
Treatment	2011	2012	2011	2012
Weed Infested for 3WAS	96.38b	94.44b	95.36bc	86.11c
Weed Infested for 6WAS	96.38b	92.58c	95.36bc	89.81bc
Weed Infested for 9WAS	97.22b	99.08ab	96.31b	94.44b
Weed Infested for 12WAS	97.22b	100.00a	97.22b	97.22a
Weed Infested until harvest	100.00a	100.00a	100.00a	99.64a
Weed Free for 3WAS	100.00a	99.08ab	99.08a	98.14a
Weed Free for 6WAS	97.22b	94.44b	95.36bc	94.44b
Weed Free for 9WAS	88.88c	95.36b	89.81c	91.67b
Weed Free for 12WAS	88.88c	89.81d	82.03d	90.75c
Weed Free until harvest	85.29d	87.03e	85.19e	87.97c
SE$\pm$	0.321	0.221	0.239	0.763

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

longer. In this location in 2012 at Samaru, stand count decrease with initial weed free period from 3WAS to harvest.   At Afaka in 2012, plots initially left weed infested for 12WAS and beyond and those kept weed free for 3WAS gave higher percentage stand count at harvest than those left weed infested for 3-9WAS and those kept weed free for 6WAS and beyond.The plots left weed infested for 3 and 6WAS and those kept weed free for 12WAS and beyond gave similar and least stand count at harvest in the trial.

4.8.3 Plant height/plant (cm)

Tables 48 and 49 show the effects of period of weed interference on plant height at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka. In Samaru 2011 and at 3WAS (Table 48), plots kept weed free until harvest gave taller plants than all the other treatments. Plots kept weed free for 3 and12WAS and those left weed infested for 6WAS and until harvest resulted in taller plants than those left weed infested for 12WAS. At 6WAS, plots initially kept weed free for 9 and 12WAS and beyond gave taller plants than those left weed infested for 6WAS and beyond. However, plots initially left weed-infested for 12WAS gave shorter plants than the remaining treatments. At 9WAS, plots initially kept weed free for 6WAS and beyond and those left weed infested for 3 and 6WAS gave similar and taller plants than those initially left weed infested for 9WAS and longer and as well as those kept weed free for 3WAS only. At 12WAS in this location, plots kept weed free for 12WAS and longer gave taller plant than those kept weed free for 3-9WAS and those left weed infested for 3WAS and beyond. The plots that were kept weed free for 6 and 9WAS and those left weed infested for 3 and 6WAS gave similar plant height and each was taller plant than by those left weed infested for 9WAS and until harvest and those kept weed free for 3WAS.

At Afaka and at 3WAS, plots initially kept weed free for 3,6 and 9WAS and until harvest and those left weed infested for 6WAS and beyond produced taller plants than those kept weed free for 12WAS and those left weed infested for 3WAS. At 6WAS, plots initially kept weed free for 3WAS and beyond and those left infested for 3-12WAS gave taller plants than those left infested until harvest. In this location at 9WAS, plots that were initially kept weed free for 12WAS and beyond gave taller plants than those left weed infested for 3WAS and beyond and those kept weed free for 3and 6WAS. In turn, plots kept weed free for 9WAS and those left weed infested for 3-12WAS gave similar plant height and each was taller plant than plots left weed infested until harvest and those that kept weed free for 3and6WAS. At 12WAS, plots kept weed free until harvest gave taller plants than all the other treatments. This was followed by plots initially kept weed free for 6-12WAS and those that left weed infested for 3and 6WAS, which were similar and gave taller plants than the remaining treatments.

At 3WAS in 2012 at Samaru (Table 49), plots initially kept weed free for 6WAS and beyond and those left weed infested for 3-9WAS gave taller plants than those that were kept weed free for 3WAS only and those left infested for 12WAS and beyond. At 6WAS, plots kept weed free for 12WAS and beyond resulted in taller plants than all the other treatments, excluding the weed free check, which in turn was higher than plots kept weed free for 3WAS and those infested for 6WAS and longer. The least values were by plots left infested for 3WAS and longer. At 9WAS in this location, plots initially kept weed free for 6WAS and beyond and those left weed infested for 3WAS only gave taller plants than those initially left weed infested for 9WAS and beyond and those kept weed free for 3WAS. At 12WAS, plots kept weed free for 6WAS and beyond, and those left weed

Table 48: Effect of Period of Weed Interferenceon Plant Height (cm) of Roselle during Wet Season of 2011, at Samaru and Afaka,

	Plant height(cm)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	41.27bc	98.03bc	126.17a	150.93b	19.33b	46.60a	56.13b	90.67b
Weed Infested for 6WAS	44.03b	96.23c	125.27a	152.20b	20.90ab	46.07a	56.20b	90.23b
Weed Infested for 9WAS	40.20bc	80.20d	99.97b	136.33c	20.90ab	42.33ab	55.67b	75.97c
Weed Infested for 12WAS	37.63c	75.87d	96.57b	132.33c	20.80ab	43.33ab	55.63b	70.13e
Weed Infested until harvest	42.07b	77.83d	99.63b	125.03d	20.17ab	37.83c	46.73de	68.43e
Weed Free for 3WAS	42.10b	98.33bc	104.73b	125.67cd	21.73a	45.50ab	50.33d	74.17cd
Weed Free for 6WAS	41.63bc	104.4abc	131.66a	150.40b	20.33ab	44.73ab	54.00c	91.53b
Weed Free for 9WAS	41.33bc	108.17a	129.33a	153.97b	20.00ab	46.17a	59.27ab	90.27b
Weed Free for 12WAS	42.17b	107.00ab	132.83a	156.80ab	19.00b	46.16a	60.40a	90.43b
Weed Free until harvest	48.17a	106.00abc	133.13a	166.47a	20.40ab	45.67ab	60.07a	100.97a
SE±	0.707	1.723	1.764	2.148	0.488	0.588	0.631	1.177

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

Table 49: Effect of Period of Weed Interference on Plant Height (cm)) of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Plant height (cm)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	34.33a	63.33bc	95.00ab	134.33a	25.07a	47.53de	75.07c	90.53a
Weed Infested for 6 WAS	33.67ab	61.00cd	92.67bc	136.67a	23.90ab	47.67de	80.60bc	95.67a
Weed Infested for 9 WAS	33.67ab	52.33f	83.33e	124 .67b	23.00abc	43.53e	55.40d	87.33b
Weed Infested for 12 WAS	32.33b	54.33ef	86.67cde	120.52b	21.43bcd	49.00cde	53.47d	83.07b
Weed Infested until harvest	33.33b	57.00def	83.67e	120.67b	21.33bcd	44.00e	55.77d	70.67c
Weed Free for 3WAS	33.33b	59.00cde	85.33de	120.62b	18.67d	50.83cd	56.20d	74.40c
Weed Free for 6WAS	34.33a	64.00bc	97.00ab	137.33a	20.50cd	54.73abc	81.10abc	90.90a
Weed Free for 9WAS	34.67a	65.00bc	101.00a	139.00a	19.10d	53.77bcd	85.43ab	91.33a
Weed Free for12WAS	34.00a	71.33a	102.00a	140.00a	20.33cd	60.97a	83.93ab	94.30a
Weed Free until harvest	34.67a	69.00ab	102.00a	140.00a	21.17bcd	58.13ab	87.23a	99.20a
SE$\pm$	0.232	1.114	1.269	2.309	0.552	1.165	1.154	3.811

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

infested for 3 and 6 WAS gave taller plants than plots kept weed free for 3WAS and those left weed infested for 9WAS and beyond.

In the same year at Afaka and at 3WAS, plots initially left weed infested for 3WAS gave taller plants than all the other treatments, except those left weed infested for 6and9WAS.Plots initially left infested for 6WAS resulted in taller plants than those kept weed free for 3-9WAS.At 6WAS, plots kept weed free for 6 and 12WAS and until harvest resulted in taller plants than those kept weed free for 3WAS as well as those left weed infested for 3WAS and longer. At 9WAS, plots initially kept weed free for 6WAS and beyond resulted in taller plants than those left weed infested for 9WAS and beyond and those kept weed free for 3WAS. Initial weed infestation for 3-6WAS resulted in taller plants than longer initial infestation, and the plot that was kept weed free for 3WAS only. At 12WAS, plots that were kept weed free for 6WAS and beyond and those left weed infested for 3and 6WAS resulted in similar and taller plants than plots left weed infested for 9WAS and beyond as well as those kept weed free for 3WAS only. However, the plots left weed infested for 9and 12WAS gave similar and taller plants than those left weed infested for longer periods.

4.8.4 Number of leaves/plant.

The effects of period of weed interference on number of leaves/plant at 3, 6, 9 and 12 WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are presented in Tables 50 and 51. At Samaru in 2011 at 3WAS (Table 50), plots initially kept weed free for 6WAS and beyond and those initially left weed infested for 3WAS only produced more number of leaves/plant than all the other treatments. At 6WAS, plots initially left infested for 3WAS and those kept weed free for 6WAS and beyond gave more number of leaves/plant than all the other treatments. At 9WAS, plots initially kept weed free for

6WAS and beyond resulted in similar and produced more number of leaves/plant than those left initiallty weed infested for 3WAS and beyond and as well as those kept weed free for 3WAS. This was followed by those left weed infested for 3and6WAS which gave more number of leaves/plant than those that left weed infested for 9WAS and beyond and those kept weed free for 3WAS. At 12WAS, plots initially kept weed free for 9WAS and beyond gave more number of leaves/plant than all the other treatments except, those kept weed free for 6WAS and plot left weed infested for 6WAS. Plots left weed infested for 3WAS, gave more number of leaves/plant than those left weed infested for 9WAS and beyond and those kept weed free for 3WAS.

In the same year at Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond and those left weed infested for 3and 6WAS as well as those left infested until harvest resulted in more number of leaves/plant than all the other treatments. At 6WAS, plots initially kept weed free for 6WAS and beyond, produced more number of leaves/plant than all the other treatments. However, plots kept weed free for 3WAS and those initially left weed infested for 3WAS gave similar and more number of leaves/plant than the remaining treatments. In this location at 9WAS, plots initially kept weed free for 6WAS and beyond resulted in more number of leaves/plant than all the other treatments. At 12WAS, plots initially kept weed free for 6WAS and beyond resulted in similar and more number of leaves/plant than those initially left weed infested for 3WAS and beyond as well as those kept weed free for 3WAS. In turn, those left weed infested for 3-9WAS were similar and recorded more number of leaves/plant than those left weed infested for 12WAS and beyond and those kept weed free for 3WAS.

In 2012 at Samaru (Table 51), at 3WAS, plots initially kept weed free until harvest gave more number of leaves/plant than all the other treatments, except those kept weed free for 6

Table 50: Effect of Period of Weed Interference on Number of Leaves/plant of Roselle during Wet Season of 2011, at Samaru and Afaka

	Number of leaves/plant							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	25.67abc	43.33a	52.67b	78.33b	14.00ab	37.00b	61.67c	90.33b
Weed Infested for 6WAS	22.67bcd	35.33bcd	53.00b	80.67ab	13.33ab	28.33c	66.67bc	94.33b
Weed Infested for 9WAS	21.00d	28.67de	42.67c	59.33c	11.67b	30.67c	50.67d	83.00b
Weed Infested for 12WAS	22.67bcd	32.33cde	44.33c	49.67c	11.67b	27.00d	48.33d	69.33c
Weed Infested until harvest	20.00d	25.67e	44.67c	54.33c	16.00ab	24.67d	44.67d	65.67c
Weed Free for 3 WAS	21.67cd	34.67bcd	46.67c	51.33c	14.00ab	37.00b	47.00d	70.67c
Weed Free for 6 WAS	28.00a	41.67ab	76.67a	85.67ab	16.33a	42.00a	76.33a	111.33a
Weed Free for 9 WAS	27.33a	41.00ab	71.00a	89.33a	16.00ab	42.00a	76.00a	110.33a
Weed Free for 12 WAS	27.33a	40.33ab	71.00a	89.33a	16.33a	45.00a	77.00a	117.67a
Weed Free until harvest	28.33a	41.00ab	74.67a	89.33a	16.00ab	43.00a	73.33ab	118.33a
SE$\pm$	0.759	0.759	1.736	1.916	0.788	0.774	1.243	1.978

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

and 9WAS and those left infected for 6WAS. At 6WAS, plots initially kept weed free until harvest resulted in more number of leaves/plant than all the other treatments, except those kept weed free for 12WAS. Plots kept weed free for 6 and 9WAS as well as those left infested for 3WAS gave similar and more number of leaves/plant than those kept weed free for 3WAS and those left weed infested for 6WAS and beyond. At 9 and 12WAS, plots initially kept weed free for 6WAS and beyond gave similar and produced more number of leaves/plant than all the other treatments.The plots initially left weed infested for 3and 6WAS gave similar which in turn recorded more number of leaves/plant than plots left weed infested for 9WAS and beyond and those kept weed free for 3WAS.

At Afaka and at 3WAS, plots initially kept weed free for 12WAS and beyond gave more number of leaves/plant than all the other treatments. Plots kept weed free for 6 and 9WAS resulted in more number of leaves/plant than those left infested for 3WAS and beyond and those kept weed free for 3WAS. At 6WAS, plots kept weed free until harvest gave more number of leaves/plant than all the other treatments. However, plots kept weed free for 6-12WAS gave similar and recorded more number of leaves/plant than those initially left weed infested for 3WAS and beyond and those kept weed free for 3WAS. At 9 and 12WAS plots initially kept weed free until harvest recorded more number of leaves than all the other treatments, except those kept weed free for 6-12WAS.

4.8.5 Number of primary branches/plant

Tables 52 and 53 show the effects of period of weed interference on number of primary branches/plant of roselle at 3, 6, 9 and 12WAS during wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011 at Samaru and at 3WAS (Table 52), period of weed interference did not influence primary branching. At 6WAS, plots initially kept weed free for 12WAS and beyond and those that left infested for 6WAS resulted in similar and

Table 51: Effect of Period of Weed Interference on Number of Leaves/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Number of leaves/plant							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	25.33cd	45.33bc	65.33b	84.00b	20.33cd	41.00c	83.67c	199.33b
Weed Infested for 6WAS	30.33ab	42.67c	66.00b	82.33b	20.00cd	37.67d	83.67c	199.67b
Weed Infested for 9WAS	23.33d	34.67d	48.00c	67.00c	20.00cd	35.00de	53.67d	90.67c
Weed Infested for 12WAS	23.00d	32.67d	49.00c	52.00d	19.67cd	34.33e	53.33d	85.00cd
Weed Infested until harvest	23.33d	31.00d	45.33c	51.00d	19.00d	33.67e	50.00d	80.40d
Weed Free for 3WAS	26.33bcd	32.67d	49.33c	52.00d	20.67cd	35.33de	54.33d	84.67cd
Weed Free for 6WAS	27.67a-d	45.67bc	76.33a	91.33a	21.80bc	47.00b	94.67ab	204.67ab
Weed Free for 9WAS	28.33abc	45.00bc	73.33a	91.67a	21.00bc	48.33b	94.67ab	201.00ab
Weed Free for 12WAS	26.67bcd	51.00ab	73.00a	93.33a	22.67a	48.33b	94.63ab	202.00ab
Weed Free until harvest	31.67a	54.33a	72.33a	92.33a	23.00a	51.67a	101.67a	210.00a
SE$\pm$	0.817	1.302	1.167	0.443	0.332	0.567	1.392	1.812

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

greater number of primary branches/plant than plots kept weed free for 3WAS and weed infested for 9WAS. At 9WAS, the weed free check gave more primary branches than the weedy check and plants kept weed free for 3WAS only. At 12WAS, plots kept weed free for 9WAS and until harvest resulted in higher number of primary branches/plant than those kept weed free for 3WAS only and those left infested for 12WAS.

At Afaka and at 3WAS, plots kept weed free until harvest gave higher number of primary branches/plant than all the other treatments. This was followed by plots initially kept weed free for 3-12WAS which in turn resulted in similar and higher number of primary branches/plant than those left infested for 3WAS and beyond. At 6WAS, plots kept weed free for 6WAS and beyond gave higher number of primary branches/plant than those left weed infested for 9WAS and beyond. At this location at 9WAS, plots kept weed free for 12WAS gave higher number of primary branches/plant than all the other treatments, except those kept weed free for 9WAS and the weed free check, each of which gave more branches than plots left initially infested for 9WAS and longer. At 12WAS, plots kept weed free for 9 and12WAS gave higher number of primary branches/plant than all the other treatments, except the weed free check and weed free for 6WAS as well as weed-infested for 3WAS, respectively, each of which produced more branches than plots left infested for 12 WAS and those kept weed free for 3WAS only.

In 2012 at Samaru (Table 53), plots initially kept weed free for 3-9WAS and until harvest and those left weed infested for 3WAS and beyond were similar and resulted in higher number of primary branches/plant than plots kept weed free for 12WAS when sampled at 3WAS. At 6WAS in this location, plots initially kept weed free for 6WAS gave higher number of primary branches than those left weed infested for 3 and 6WAS and until

Table 52: Effect of Period of Weed Interference on Number of Primary Branches/plant of Roselle during Wet Season of 2011, at Samaru and Afaka

	Numbers of primary branches/plant							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	1.67	4.00ab	6.67ab	8.00ab	0.10c	1.33ab	3.00bc	5.00abc
Weed Infested for 6WASs	2.00	4.67a	7.33ab	9.00ab	0.10c	1.33ab	3.00bc	4.00cde
Weed Infested for 9WAS	1.67	3.67b	6.00ab	8.00ab	0.10c	1.00b	2.00d	4.00cde
Weed Infested for 12WAS	2.00	4.00ab	6.00ab	7.33b	0.10c	1.00b	1.67d	3.67de
Weed Infested until harvest	2.00	4.00ab	5.33b	8.00ab	0.10c	1.00b	2.33cd	4.33bcd
Weed Free for 3 WAS	2.00	3.67b	5.33b	7.33b	1.00b	1.33ab	2.33cd	3.00e
Weed Free for 6 WAS	2.00	4.00ab	7.67ab	8.67ab	1.00b	2.00a	3.00bc	5.00abc
Weed Free for 9 WAS	2.33	4.00ab	7.67ab	10.33a	1.00b	2.00a	3.67ab	5.67a
Weed Free for 12 WAS	2.33	4.33a	7.67ab	8.33ab	1.00b	2.00a	4.00a	6.00a
Weed Free until harvest	1.67	4.33a	8.67a	10.00a	2.00a	2.00a	3.67ab	5.33ab
SE$\pm$	0.142	0.223	0.271	0.441	0.061	0.133	0.142	0.206

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

harvest. At 9WAS, plots left weed infested for 3WAS gave higher number of primarybranches/plant than all the others except those infested for 3WAS and the weed free check. The weed free check produced more branches than the weed infested for 12WAS and the weedy check, as well as the weed free for 3WAS. At 12WAS, plots kept weed free for 9WAS and beyond gave higher number of primary branches/plant than all the other treatments, except those kept weed free for 12WAS. In turn, plots kept weed free for 6WAS gave higher number of primary branches/plant than those kept weed fre for 3WAS and those left weed infested for 3WAS and beyond.

At 3WAS in Afaka, plots kept initially weed free until harvest gave higher number of primary branches/plant than all the other treatments. This was followed by plots kept initially weed free for 3, 9 and 12WAS which resulted in similar and higher number of primary branches/plant than those kept weed free for 6WAS and those left infested for 3WAS and beyond. At 6WAS, plot kept weed free until harvest resulted in higher number of primary branches/plant than all the other treatments. In turn plots kept weed free for 6-12WAS gave higher number of primary branches/plant than those left weed infested for 6 and 12WAS and those kept weed free for 3WAS only. At 9WAS, plots kept weed free for 9WAS and beyond were similar and gave higher number of primary branches/plant than all the other treatments. The plots initially kept weed free for 6WAS and those left weed infested for 6WAS only resulted in higher number of primary branches/plant than those left weed infested for 9WAS and beyond. In this location at 12WAS, plots kept initially weed free for 9and 12WAS gave higher number of primary branches/plant than all the other treatments. This was followed by those kept weed –free for 6WAS, those that kept weed free until harvest and those plots left infested 3WAS only, each of which in turn gave higher values than by the remaining treatments.

Table 53: Effect of Period of Weed Interference on Number of Primary Branches/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Number of primary branches/plant							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	2.33a	3.67bc	7.33abc	8.33c	0.33c	1.67bc	3.00b	5.00bc
Weed Infested for 6WAS	2.33a	3.67bc	8.00a	8.00c	0.10c	1.00c	2.67bc	4.67cd
Weed Infested for 9WAS	2.33a	4.33abc	6.33bcd	7.00cd	0.10c	1.33bc	2.00c	3.67ef
Weed Infested for 12WAS	2.00a	4.00abc	6.00cd	7.33cd	0.10c	1.00c	2.00c	2.67g
Weed Infested until harvest	2.00a	3.33c	5.33cd	7.33cd	0.33c	1.33bc	2.00c	4.00de
Weed Free for 3 WAS	2.33a	5.00ab	5.67cd	8.33c	1.00b	1.00c	2.00c	3.00fg
Weed Free for 6 WAS	2.00a	5.33a	6.33bcd	10.33b	0.33c	1.33bc	3.00b	5.00bc
Weed Free for 9 WAS	2.00a	4.67abc	6.67bcd	11.33a	1.00b	2.00b	4.00a	6.00a
Weed Free for 12 WAS	1.67b	4.00abc	6.33bcd	10.67a	1.00b	2.00b	4.00a	5.67ab
Weed Free until harvest	2.67a	4.67abc	7.67ab	11.00a	2.00a	3.00a	4.00a	5.00bc
SE±	0.185	0.246	0.234	0.308	0.093	0.127	0.161	0.153

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT

4.8.6 Number secondary branches/plant

Tables 54 and 55 presents the effects of period of weed interference on number of secondary branches/plant of roselle at 6, 9 and 12WAS during the wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011 at Samaru and at 6WAS (Table 54), plots initially kept weed free for 6WAS and beyond and those left weed infested for 3WAS only, gave higher number of secondary branches/plant than those left infested for 6WAS and beyond as well as those kept weed free for 3WAS. Plots left weed infested for 6WAS gave higher number of secondary branches/plant than the rest of the treatments. At 9WAS, plots kept weed free until harvest resulted in higher number of secondary branches/plant than all the other treatments which was at *par* with those kept weed free for 6-12WAS and those left infested for 3WAS. This was followed by plots left infested for 6WAS, which in turn gave higher number of secondary branches /plant than the rest of the treatments. At 12WAS, plot kept initially weed free until harvest gave higher number of secondary branches than all the other treatments. However, plots kept weed free for 9 and 12WAS resulted in higher number of secondary branches/plant than those kept weed free from 3and6WAS and those left infested for 3WAS and beyond.

At Afaka and at 3WAS, plots initially kept weed free until harvest gave higher number of secondary branches/plant than all the other treatments. Plots kept weed free for 12WAS gave higher number of secondary branches/plant than those left weed infested for 3WAS and beyond and those kept weed free for 3-9WAS. At 9WAS, the weed free check gave higher number of secondary branches/plant than all the other treatments. This was followed by plots kept weed free for 6-12WAS which gave similar and recorded higher number of secondary branches/plant than plots left weed infested for 3WAS and beyond and those kept weed free for 3WAS. At this location at 12WAS, plots kept weed free until harvest resulted in higher number of secondary branches/plant than all the other treatments, except those kept weed free for 9 and 12WAS.

In 2012 at Samaru (Table 55), at 6WAS, the weed free check recorded higher number of secondary branches/plant than all the other treatments, except those kept weed free until harvest. At 9WAS, plots initially kept weed free for 6WAS and beyond and those left weed infested for 3and6WAS resulted in similar and higher number of secondary branches/plant than all the other treatments. At this location at 12WAS, plots initially kept weed free for 6WAS and beyond gave higher number of secondary branches/plant than all the other treatments, except those left weed infested for 6WAS. Plots left weed infested for 3WAS only was however recorded higher number of secondary branches/plant than the rest of the treatments.

At Afaka and at 3WAS, plots initially kept weed free for 3WAS and beyond gave higher number of secondary branches/plant than all the other treatments, except those kept weed free for 3WAS, those left weed free for 3WAS as well as 12WAS and beyond. At 9WAS, plots kept weed free for 6WAS and beyond recorded higher number of secondary branches/plant than all the other treatments.This was followed by plots left weed infested for 3and6WAS which gave higher number of secondary branches/plant than polts left weed infested for 9WAS and beyond and those that kept weed free for 3WAS. At 12WAS, plots initially kept weed free for 9WAS and beyond resulted in higher number of secondary branches/plant than all the other treatments, except those kept weed free for 6WAS.

Table 54: Effect of Period of Weed Interference on Number of Secondary Branches/plantof Roselle during Wet Season of 2011, at Samaru and Afaka.

	Number of secondary branches/plant					
	Samaru			Afaka		
Treatment	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	12.00a	16.00ab	19.33c	0.10d	2.33c	3.33cd
Weed Infested for 6WAS	7.67b	14.67b	20.33bc	0.33cd	2.67c	3.67c
Weed Infested for 9WAS	5.33bc	8.33c	10.67d	0.10d	1.00d	1.67e
Weed Infested for 12WAS	5.00bc	6.67c	8.33e	0.10d	1.00d	1.00e
Weed Infested until harvest	4.33c	6.00c	8.33e	0.10d	1.33d	2.00de
Weed Free for 3 WAS	6.33bc	8.00c	8.33e	0.33cd	1.33d	2.00de
Weed Free for 6 WAS	11.67a	17.33ab	19.33c	1.00bcd	3.67b	4.67bc
Weed Free for 9WAS	11.33a	16.00ab	21.33b	1.33bc	3.67b	5.33ab
Weed Free for 12 WAS	12.33a	17.00ab	22.00b	1.67b	4.33b	5.33ab
Weed Free until harvest	13.33a	18.67a	24.00a	3.00a	6.33a	6.33a
SE$\pm$	0.432	0.563	0.340	0.225	0.166	0.292

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT

Table 55: Effect of Period of Weed Interference on Number of Secondary Branches/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Number of secondary branches/plant					
	Samaru			Afaka		
Treatment	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	15.00bc	24.00a	24.00b	1.00ab	1.67b	6.00c
Weed Infested for 6WAS	8.67d	22.33a	24.67ab	0.33b	1.33b	6.67bc
Weed Infested for 9WAS	7.33d	11.00b	13.67c	0.33b	0.67c	4.00d
Weed Infested for12WAS	7.33d	10.00b	11.00d	0.67ab	0.67c	3.33d
Weed Infested until harvest	7.33d	10.00b	11.33d	0.67ab	0.67c	3.00d
Weed Free for 3WAS	7.33d	10.33b	12.33cd	0.67ab	1.00c	3.00d
Weed Free for 6WAS	13.67c	23.00a	26.00a	1.67a	2.67ab	7.33abc
Weed Free for 9WAS	14.33bc	23.00a	26.00a	1.67a	2.67ab	8.33a
Weed Free for 12WAS	16.00ab	23.00a	25.67a	1.67a	3.33a	8.33a
Weed Free until harvest	17.00a	24.00a	26.00a	1.67a	3.00a	7.67ab
SE$\pm$	0.338	0.355	0.273	0.185	0.223	0.262

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

4.8.7 Number of tertiary branches/plant.

Tables 56 and 57 show the effects of period of weed interference on number of tertiary branches/plant of roselle at 6, 9 and 12WAS during wet seasons of 2011 and 2012 at Samaru and Afaka. In 2011 at Samaru (Table 56) at 3WAS, plots initially kept weed free for 9 and12WAS resulted in similar and higher number of tertiary branches/plant than all the other treatments.This was followed by plots kept weed free for 6WAS and until harvest which gave higher number of tertiary branches/plant than the rest of the treatments. At 9WAS, plots initially kept weed free for 9 and 12WAS resulted in higher number of tertiary branches/plant than all the other treatments, except those kept weed free until harvest. This was followed by plots kept weed free for 6WAS and those left weed infested for 3and 6WAS, which in turn gave higher number of tertiary branches/plant than the rest of the treatments. At 12 WAS, plots initially kept weed free for 9 and 12WAS resulted in higher number of teriary branches/plant than all the other treatments, except those kept weed free for 6 and until harvest.This was followed by plots left weed infested for 3and 6WAS which in turn gave higher number of tertiary branches than the rest of the treatments.

In the same season at Afaka and at 3WAS, plots initially kept weed free until harvest gave higher number of tertiary branches/plant than all the other treatments.The plots kept weed free for 6-12WAS resulted in similar and higher number of tertiary branches/plant than the remaining treatments.At 9WAS, plots initially kept weed free for 9WAS and beyond resulted in similar and higher number of tertiary branches /plant than the remaining treatments.Plot kept weed free for 6WAS was however recorded higher number of tertiary branches/plant than the rest of the treatments. At 12WAS, plots initially kept weed free for 12WAS gave higher number of tertiary branches/plant than the remaining treatments,

Table 56: Effect of Period of Weed Interference on Number of Tertiary Branches/plant of Roselle during Wet Season of 2011, at Samaru and Afaka.

	Number of tertiary branches/plant					
	Samaru			Afaka		
Treatment	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	4.67c	6.67b	8.33b	0.10c	2.00c	3.33c
Weed Infested for 6WAS	4.00cd	6.67b	8.67b	0.10c	2.00c	3.33c
Weed Infested for 9WAS	3.33de	4.00c	6.33c	0.10c	1.00d	2.00d
Weed Infestedfor12WAS	3.00e	3.33c	5.00d	0.10c	1.00d	1.00e
Weed Infested until harvest	3.33de	3.67c	3.67e	0.10c	1.00d	1.67de
Weed Free for 3WAS	3.00e	3.33c	4.67de	0.10c	1.00d	1.67de
Weed Free for 6 WAS	6.00b	7.00b	9.00ab	1.00b	2.67b	4.67b
Weed Free for 9 WAS	7.33a	8.23a	10.00a	1.00b	4.00a	5.33ab
Weed Free for 12 WAS	8.00a	8.33a	10.00a	1.00b	4.33a	5.67a
Weed Free until harvest	6.00b	7.33ab	9.00ab	2.00a	4.00a	5.33ab
SE±	0.145	0.283	0.206	0.001	0.091	0.167

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

except those kept weed free for 9 and until harvest. Plots kept weed free for 6WAS only recorded higher number of tertiary branches/plant than the rest of the treatments.

In 2012 at Samaru (Table 57) and at 3WAS, plots initially kept weed free until harvest gave higher number of tertiary than all the other treatments. This was followed by plots kept weed free for 6-12WAS which were similar and resulted in higher number of tertiary branches/plant than the rest of the treatments. At 9 and 12WAS, plots kept weed free until harvest gave higher number of tertiary branches/plant than all the other treatments, except those kept weed free for 9and12WAS.

At Afaka and at 3WAS, plots initially kept weed free until harvest resulted in higher number of tertiary branches/plant than all the other treatments, except those kept weed free for 6WAS and those left weed infested for 6WAS. At 9WAS, weed free check gave higher number of tertiary branches than all the other treatments. Plots kept weed free for 9WAS and those left weed infested for 3WAS recorded higher number of tertiary branches than the remaining treatments. At 12WAS, plots initially kept weed free for 6WAS and until harvest and those left weed infested for 3and6WAS resulted in similar and higher number of tertiary branches than all the other treatments. This was followed by those kept weed fee for 9WAS which in turn recorded higher number of tertiary branches/plant than the rest of the treatments.

4.8.8 Stem girth/plant (mm)

Effects of period of weed interference on stem girth at 3, 6, 9 and 12WAS of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka are shown in Tables 58 and 59. In 2011 at Samaru and at 3WAS (Table58), plots initially kept weed free for 12WAS gave thicker stem than all the other treatments, except those kept weed free for 9WAS and until harvest. At 6WAS, plots kept weed free for 12WAS gave thicker stem than all the other treatments, except those initially left weed infested for 3 and 6WAS and those kept weed free for 3-9WAS and until harvest. At 9WAS, plots initially kept weed free until harvest resulted in thicker stem than all the other treatments which was comparable with those kept weed free for 12WAS. At 12WAS, plots initially kept weed free for 12WAS gave thicker stem than all the other treatments, except those kept weed free for 9WAS and until harvest.

At Afaka, weed interference did not have significant effect on stem girth when sampled at 3WAS. At 6WAS, plots initially kept weed free for 12WAS and until harvest gave thicker stem than all the other treatments, except those kept weed free for 6 and 9WAS. In this location at 9WAS, plots kept weed free for 9WAS and beyond gave similar and thicker stem than all the other treatments. This was followed by plots kept weed free for 6WAS and those left weed infested for 3and 6WAS which gave similar and thicker stem than the remaining treatments. At 12WAS, plots kept weed free until harvest gave thicker stem than all the other treatments, except those kept weed free for 12WAS.

In 2012 at Samaru and at 3WAS (Table 59), plots initially kept weed free for 6WAS and beyond resulted in thicker stem than all the other treatments, except those kept weed free for 3WAS and those left weed infested for 3-9WAS. At 6WAS, plots initially kept weed free for 12WAS and until harvest recorded thicker stem than all the other treatments, except those kept weed free for 9WAS and those left infested for 3WAS. This was followed by plots kept weed free for 6WAS and those left weed infested for 6WAS which gave similar stem girth and thicker than the rest of the treatments. At 9WAS, plots initially kept weed free until harvest resulted in thicker stem than all the other treatments, except those kept weed free for 12WAS. At 12WAS, plots initially kept weed free for 12WAS and beyond stem than all the other treatments, except those kept weed free for 6-12WAS when sampled at 6WAS. At 9WAS, plots initially kept weed free until harvest gave thicker stem than all

Table 57: Effect of Period of Weed Interference on Number of Tertiary Branches/plant of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Number of tertiary branches/plant					
	Samaru			Afaka		
Treatment	6WAS	9WAS	12WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	4.67c	9.33bc	10.67cd	1.00bc	2.33b	4.00a
Weed Infested for 6WAS	4.67c	8.67c	10.00d	1.33ab	1.67bc	4.00a
Weed Infested for 9WAS	3.00d	3.67d	7.00e	0.10d	0.10e	1.67c
Weed Infestedfor12WAS	2.33d	3.33d	7.00e	0.10d	0.10e	0.67d
Weed Infested until harvest	2.33d	3.67d	7.00e	0.33cd	0.33de	2.00bc
Weed Free for 3 WAS	2.67d	4.00d	8.00e	0.33cd	1.00cd	2.00bc
Weed Free for 6 WAS	7.67b	9.00c	11.67bc	1.33ab	1.67bc	4.33a
Weed Free for 9 WAS	7.67b	9.67ab	12.67ab	1.00bc	2.00b	3.67b
Weed Free for 12 WAS	7.67b	10.33ab	12.67ab	1.00bc	1.67bc	1.67c
Weed Free until harvest	8.67a	11.00a	14.00a	2.00a	4.00a	5.00a
SE$\pm$	0.178	0.225	0.265	0.169	0.158	0.333

WAS: Weeks after sowing.

Means followed by the same letter(s) with a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT

Table 58: Effect of Period of Weed Interference on Stem Girth (mm) of Roselle during Wet Season of 2011, at Samaru and Afaka

	Stem girth(mm)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	2.60cd	3.13ab	3.57c	4.07cd	1.00	1.40bc	1.87b	2.60e
Weed Infested for 6WAS	2.50de	3.00abc	3.57c	4.10cd	1.00	1.27de	1.87b	2.73cd
Weed Infested for 9WAS	2.43efg	2.77bc	3.06d	3.90d	1.00	1.20ef	1.40c	2.33f
Weed Infested for 12WAS	2.37fg	2.67c	3.03d	3.40e	1.00	1.10f	1.40c	1.80g
Weed Infested until harvest	2.33g	2.67c	3.00d	3.33c	1.00	1.13f	1.40c	1.67g
Weed Free for 3WAS	2.47ef	3.00abc	3.03d	3.40e	1.00	1.33cd	1.47c	1.80g
Weed Free for 6WAS	2.63bc	3.13ab	3.57c	4.33bc	1.00	1.47abc	2.00b	2.80cd
Weed Free for 9WAS	2.70abc	3.17ab	3.63bc	4.60ab	1.00	1.43abc	2.53a	2.93bc
Weed Free for 12WAS	2.76a	3.33a	3.73ab	4.73a	1.00	1.50ab	2.67a	3.03ab
Weed Free until harvest	2.73ab	3.00abc	3.77a	4.67ab	1.00	1.57a	2.73a	3.13a
SE$\pm$	0.022	0.075	0.022	0.066	0.000	0.026	0.062	0.026

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

Table 59: Effect of Period of Weed Interference on Stem Girth (mm) of Roselle during Wet Season of 2012, at Samaru and Afaka.

	Stem girth(mm)							
	Samaru				Afaka			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Weed Infested for 3WAS	2.80ab	3.53ab	4.23cd	4.87b	1.80a	2.31bc	2.93b	3.33d
Weed Infested f or 6WAS	2.80ab	3.40b	4.23cd	4.87b	1.80a	2.20c	2.77c	3.33d
Weed Infested for 9WAS	2.73ab	3.07d	3.47e	4.23d	1.70b	2.07c	2.20d	2.73e
Weed Infested for 12WAS	2.67b	3.03d	3.30e	3.73e	1.50c	2.07c	2.20d	2.53f
Weed Infested until harvest	2.67b	3.00d	3.33e	3.70e	1.80a	2.07c	2.17d	2.60f
Weed Free for 3WAS	2.77ab	3.23c	3.47e	3.87e	1.70b	2.33c	2.13d	2.53f
Weed Free for 6WAS	2.87a	3.47b	4.13d	4.67c	1.70b	2.53ab	2.87bc	3.53c
Weed Free for 9WAS	2.87a	3.53ab	4.43bc	4.70b	1.70b	2.53ab	2.90bc	3.73b
Weed Free for12WAS	2.87a	3.70a	4.53ab	5.07a	1.70b	2.60ab	2.93b	3.77b
Weed Freeuntil harvest	2.87a	3.67a	4.67a	5.20a	1.80a	2.73a	3.20a	3.93a
SE$\pm$	0.024	0.031	0.040	0.036	0.006	0.053	0.027	0.022

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

the other treatments, This was followed by plots kept initially weed free for 12WAS and those left weed infested for 3WAS resulted in thicker stem than the rest of the treatments. At 12WAS, plots kept weed free until harvest gave thicker stem than all the other treatments.This was followed by plots kept weed free for 9and12WAS which resulted in similar and thicker stem than the remaining treatments.

4.8.9 Days to 50% flowering

The effect of period of weed interference on number of days to 50% flowering of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka is shown in Table 60. In 2011 and 2012 at Samaru (Table 60), plots initially left weed-infested for 12WAS and until harvest increased number of days to 50% flowering compared to all the other treatments, which were similar. In both years at Afaka, weed interference did not interefer with the number of days to 50% flowering in roselle.

4.8.10 : Days to physiological crop maturity

The effect of period of weed interference on days to physiological crop maturity of roselle during wet seasons of 2011 and 2012 at Samaru and Afaka is presented in (Table 61). The days to physiological crop maturity of roselle was significantly affected in 2012 at Samaru and in 2011 at Afaka (Table 61). In 2012 at Samaru, the weedy check and plots left infested for 12WAS delayed in days to physiological crop maturity compared to all the other treatments which were similar to each other.

In 2011 at Afaka, plots left infested for 9WAS delayed physiological crop maturity compared to all other treatments, except those plots infested for 12WAS and that kept weed-free for 3WAS only.

4.9 Yield and Yields Components

4.9.1 Number of calyx/plant.

The effect of period of weed interference on number of calyx/plant of roselle during wet seasons of 2011and 2012 and the combined data at Samaru and Afaka is presented in Table 62. In both locations and combined data, period of weed interference significantly influenced number of calyx/plant. In 2011 at Samaru plots initially kept weed free for 6WAS and longer resulted in more number of calyx/plant than all the other treatments. This was followed by plots initially left weed infested for 3WAS only, which in turn recorded more number of calyx/plant than plots left weed infested for 6WAS and beyond and those kept weed free for 3WAS. The plots left weed infested for 6WAS gave more number of calyx than those left weed infested for 9WAS and beyond and as well as those kept weed free for 3WAS. The later in turn resulted in more number of calyx/plant than those left weed infested for 9WAS and until harvest. The least number of calyx/plant was by plots left weed infested for 9WAS.

In 2012 in this location, the plots initially kept weed free for 6WAS and beyond and those left weed infested for 3WAS only resulted in similar and more number of calyx/plant than all the other treatments.The plots left weed infested for 6WAS however, recorded more number of calyx/plant than those left weed infested for 9WAS and beyond and those kept weed free for 3WAS only. The number of calyx/plant by the plots initially kept weed free for 3WAS and those left infested for 9WAS were similar to the lowest by those plots left weed infested for 12WAS and beyond. In the combined data, plots initially kept weed free for 6WAS and longer gave more number of calyx/plant than all the other treatments.This was followed by plots left weed infested for 3WAS, which in turn gave more number of

Table 60: Effect of Period of Weed Interference on Days to 50% Flowering of Roselle during Wet Sessions of 2011 and 2012 at Samaru and Afaka.

	Days to 50% flowering			
	Samaru		Afaka	
Treatment	2011	2012	2011	2012
Weed Infested for 3WAS	89.00b	89.00b	90.00	89.00
Weed Infested for 6WAS	89.00b	89.00b	90.00	89.00
Weed Infested for 9WAS	89.00b	89.00b	90.00	89.00
Weed Infested for 12WAS	90.00a	90.00a	90.00	89.00
Weed Infested until harvest	90.00a	90.00a	90.00	89.00
Weed Free for 3WAS	89.00b	89.00b	90.00	89.00
Weed Free for 6WAS	89.00b	89.00b	90.00	89.00
Weed Free for 9WAS	89.00b	89.00b	90.00	89.00
Weed Free for 12WAS	89.00b	89.00b	90.00	89.00
Weed Free until harvest	89.00b	89.00b	90.00	89.00
SE±	0.061	0.036	0.000	0.000

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 61: Effect of Period of Weed Interference on Days to Physiological Crop Maturity of Roselle during Wet Seasons of 2011 and 2012 at Samaru and Afaka

	Days to physiological crop maturity			
	Samaru		Afaka	
Treatment	2011	2012	2011	2012
Weed Infested for 3WAS	130.00	130.67b	132.33b	130.00
Weed Infested for 6WAS	132.33	130.33b	132.33b	130.00
Weed Infested for 9WAS	132.67	130.00b	134.33a	130.00
Weed Infested for 12WAS	130.00	132.00a	133.33ab	130.33
Weed Infested until harvest	130.00	132.00a	132.33b	130.33
Weed Free for 3WAS	131.67	130.33b	133.33ab	130.00
Weed Free for 6WAS	132.33	130.00b	132.33b	130.00
Weed Free for 9WAS	131.67	130.33b	132.33b	130.00
Weed Free for 12WAS	132.33	131.00b	132.33b	130.00
Weed Freeuntil harvest	132.67	130.33b	132.33b	130.00
SE$\pm$	7.302	0.061	0.292	0.081

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

calyx/plant than plots left weed infested for 6WAS and beyond and those kept weed free for 3WAS.The plots left weed infested for 6WAS also resulted in more number of calyx/plant than those left weed infested for 9WAS and beyond and as well as those initially kept weed free for 3WAS. In short, the number of calyx/plant decreased with increase in weed infestation period from 3-12WAS in both years and from 3WAS to harvest in the combined mean.

At Afaka, plots initially kept weed free for 6WAS and longer gave similar and number of calyx/plant than all the other treatments in both years and the combined mean. In 2011 and 2012, the number of calyx/plant decreased with increase in initial weed infestation period from 3-12WAS, and 6-12WAS in the combined data. Initial weed infestation for 3-6WAS gave more calyx/plant than initially kept weed free period of 3WAS.

4.9.2 Calyx weight/plant (g)

The effect of period of weed interference on calyx weight/plant of roselle during wet seasons of 2011 and 2012 and combined data at Samaru and Afaka is shown in Table 63. At Samaru in both years and combined mean, keeping plots initially weed free for 6WAS and longer and initially weed infested for 3-6WAS gave similar and higher calyx weight/plant than initial weed free for 3WAS and initial weed infestation for 9WAS and beyond. In each case, calyx weight/plant decreased as the period of initial weed infestation was increased from 6weeks to crop harvest. Initial weed free period of 3 weeks was similar to the weedy check.

In 2011 at Afaka, plots initially kept weed free until harvest gave higher calyx weight /plant than all the other treatments.This was followed, by plots initially kept weed free for 6-12WAS, which were similar and also gave higher calyx weight/plant than those left weed infested for 3WAS and beyond as well as those kept weed free for 3WAS only. In 2012 and

Table 62: Effect of Period of Weed Interference on Number of Calyx/plant of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

	Number of calyx/plant					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	202.00b	229.33a	215.67b	12.00c	16.10b	14.05b
Weed Infested for 6WAS	192.33c	198.33b	195.33c	10.27d	14.83bc	12.55b
Weed Infested for 9WAS	101.67e	109.67c	105.67e	6.00f	11.27d	8.64c
Weed Infested for 12WAS	96.67f	102.00d	99.34g	5.33g	7.97f	6.66d
Weed Infested until harvest	99.00e	103.67d	101.34f	5.97f	7.67f	6.82d
Weed Free for 3WAS	162.06d	110.67c	136.37d	7.07e	8.87e	7.97c
Weed Free for 6WAS	212.00a	228.67a	220.34a	15.27a	19.49a	17.38a
Weed Free for 9WAS	212.00a	229.00a	220.50a	14.00b	19.50a	16.75a
Weed Free for 12WAS	214.00a	229.33a	221.67a	14.00b	20.03a	17.02a
Weed Freeuntil harvest	210.00ab	229.67a	219.84a	14.33b	20.03a	17.18a
SE$\pm$	1.735	0.601	0.649	0.090	0.071	0.081

WAS: Weeks after sowing.
Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

combined mean, plots initially kept weed-free for 6WAS and longer and those left weed infested for 3and6WAS resulted in higher calyx weight than those initially left infested for 9WAS and longer as well as those initially kept weed free for 3WAS only.

4.9.3 Calyx yield

Table 64 show the effect of period of weed interference on calyx yield of roselle during wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka. In both years and locations, period of weed interference significantly influenced calyx yield. In 2011 and combined data at Samaru, plots initially left weed infested for 3WAS only and those kept weed free for 6-12WAS resulted in higher calyx yield than those left weed infested for 6WAS and beyond , those kept weed free until harvest and t as well as those kept weed free for 3WAS only. In each case calyx yield progressively decrease with increase in initial weed infestation period from 3WAS to crop harvest. In 2012 at Samaru, plots initially kept weed free for 9 and12WAS and those left infested for 3WAS only gave similar and higher calyx yield than the other treatments including those kept weed free for 3-6WAS and the weed free control. In the same vein in this year, calyx yield decreased with increased with weed infestation period for 3WAS to crop harvest.

In 2011 at Afaka, plots initially kept weed-free for 6WAS and longer gave higher calyx yield than those kept weed free for 3WAS only and those left weed infested for 3WAS and beyond. The plots left weed infested for 3and6WAS resulted in similar and higher calyx yield than those left weed infested for 9WAS and beyond and those kept weed free for 3WAS.The calyx yield by the plot left weed-free for 9WAS was higher than the rest of the treatments. In 2012, plots kept weed free for 9WAS and longer resulted in higher calyx yield than all the other weed interference treatments, followed by plots kept weed free for 6WAS and those left weed infested for 3WAS, each of which in turn gave higher calyx

Table 63: Effect of Period of Weed Interference on Calyx Weight/plant (g) of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

	Calyx weight/plant (g)					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	803.33a	875.00a	839.17a	47.27c	70.07ab	58.67a
Weed Infested for 6WAS	806.67a	875.33a	841.00a	47.17c	70.03ab	58.60a
Weed Infested for 9WAS	503.33b	767.33b	635.33b	30.73d	46.10c	38.42b
Weed Infested for 12WAS	459.67c	453.00c	456.33c	28.15f	44.27c	36.21b
Weed Infested until harvest	427.00d	399.00d	413.00d	28.07f	44.40c	36.24b
Weed Free for 3WAS	413.67d	398.00d	405.84d	29.54e	42.47c	36.01b
Weed Free for 6WAS	811.67a	874.00a	842.84a	48.28b	70.70ab	59.40a
Weed Free for 9WAS	812.33a	875.67a	844.33a	48.36b	71.60ab	59.98a
Weed Free for 12WAS	812.33a	876.33a	844.33a	48.37b	72.00ab	60.19a
Weed Freeuntil harvest	831.67a	876.33a	854.00a	49.73a	74.87a	57.80a
SE$\pm$	6.002	6.661	6.332	0.090	3.842	1.966

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

yield than weed infestation for 6WAS and beyond and weed free for 3WAS.The least yield was by the plots kept weed free for 3WAS only and that left infested throughout the crop life-cycle. In the combined data at this location, plots kept weed free for 9WAS and beyond gave higher yield than all the other treatments. This was followed by plots kept weed free for 6WAS, plots left weed infested for 3, 6 and 9WAS in the decreasing order. The least yield was by plots left weed infested until harvest and those that kept weed free for 3WAS only.

4.9.4 Number of seeds/capsule

The effect of period of weed interference on number of seeds/capsule of roselle during wet seasons of 2011 and 2012 and the combined data at Samaru and Afaka is shown in Table 65. In 2011 and 2012 at Samaru, plots initially kept weed free for 3WAS and beyond resulted in similar and more number of seeds/capsule with those left initially weed infested for the respective periods. In the combined data, plots initially kept weed free for 12WAS and until harvest gave similar and number of seeds/capsule than all the other treatments which were also similar to each other. However, the plots initially kept weed free for 3-9WAS and those initially left weed infested for 3WAS and beyond gave similar to the highest by the plots initially kept weed free for 9WAS.

In 2011 at Afaka, plots initially kept weed free for 6WAS and beyond and those initially left weed infested for 3 and 6WAS gave similar and more number of seeds/capsule than those left weed infested for 9WAS and beyond and those kept initially weed free for 3WAS only. In the same location 2012, plots initially left weed infested for 3-12WAS and those initially kept weed free for 3WAS and beyond gave similar and more number of seeds/capsule than those left weed infested until harvest, which was the least in the trial. In the combined data, plots initially kept weed free for 6WAS and beyond resulted in similar

Table 64: Effect of Period of Weed Interference on Calyx yield/ha(kg) of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka.

	Calyx yield/ha(kg)					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	1813.00a	1993.60a	1903.30a	133.33b	1494.45b	8138.90c
Weed Infested for 6WAS	1586.10c	1702.80c	1644.40c	133.33b	1450.00c	7916.65d
Weed Infested for 9 WAS	1019.40d	1377.80d	1198.10d	75.00c	869.45d	472.22e
Weed Infested for 12WAS	705.60e	819.40e	762.00e	58.33d	821.67e	440.00f
Weed Infested until harvest	711.40e	811.10e	761.75e	58.33d	806.39f	432.36g
Weed Free for 3WAS	700.00e	738.90f	719.45f	66.67d	802.77f	434.72g
Weed Free for 6WAS	1799.10a	1976.10a	1887.10a	150.00a	1493.89b	8219.45b
Weed Free for 9WAS	1813.90a	1991.80a	1897.85a	149.00a	1554.45a	8517.25a
Weed Free for 12WAS	1811.10a	1997.40a	1904.75a	149.00a	1550.00a	8495.00a
Weed Freeuntil harvest	1775.00b	1941.70b	1858.35b	150.00a	1544.44a	8472.22a
SE±	6.147	6.929	6.538	0.875	1.489	0.182

WAS: Weeks after sowing

Means followed by the same letter (s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

Table 65: Effect of Period of Weed Interference on Number of Seeds/capsule of Roselle during Wet Seasons of 2011,2012 and Combined at Samaru and Afaka

	Number of seeds/capsule					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	34.67	33.67	34.17b	24.89a	27.85a	26.37b
Weed Infested for 6WAS	34.57	33.83	34.20b	24.96a	27.67a	26.32b
Weed Infested for 9WAS	34.67	33.58	34.13b	24.67b	28.67a	26.67ab
Weed Infested for 12WAS	34.52	33.56	34.01b	24.00b	27.85a	25.93b
Weed Infested until harvest	34.67	33.49	34.08b	24.00b	26.33b	25.92b
Weed Free for 3WAS	34.48	33.67	34.08b	24.64b	27.92a	26.28b
Weed Free for 6WAS	34.52	33.67	34.10b	25.67a	29.00a	27.34a
Weed Free for 9WAS	34.85	34.00	34.43b	25.33a	29.00a	27.17a
Weed Free for 12WAS	35.00	33.67	34.34a	26.00a	29.00a	27.50a
Weed Freeuntil harvest	34.82	34.67	34.75a	25.00a	30.33a	28.17a
SE$\pm$	0.197	0.172	0.184	0.430	0.603	0.517

WAS: Weeks after sowing.

Means followed by the same letter(s) within a column are not significantly different at $P \leq 0.05$ level of probability using DMRT.

and more number of seeds/capsule than all the other treatments, except the initially weed infested plots for 9WAS.

4.9.5 Weight of seeds/capsule

The effect of period of weed interference on weight of seeds/capsule of roselle during wet seasons of 2011and 2012 and the combined data at Samaru and Afaka is presented in Table 66. In 2011 and 2012 and the combined data at Samaru and Afaka, period of weed interference did not significantly influence seed weight/capsule.

4.9.6 100-seed weight

The effect of period of weed interference on 100 seed weight of roselle during wet seasons of 2011, 2012 and the combined data at Samaru and Afaka are presented in Table 67. In 2011 and 2012 and combined data at both locations, this character was not influenced by period of weed interference.

4.10 Regression Analysis

Roselle calyx yield/ha obtained in the two years and combined and locations were plotted against plot kept weed-free for 3WAS and to the harvest and those left weed-infested for the corresponding periods on the other hand and are presented in Fgures 1-6.

In 2011 and 2012 at Samaru, for 25 and 50% reductions in the potential calyx yield, initial weed-free periods of 26.6 and 22.4 days after sowing (DAS) and 29.4 and 23.8 DAS were required, respectively as shown in Figures 1 and 2. For similar reductions in the yield, initial weed-infestations of 57.4 and 72 (DAS) and 59.0 and 84.0 DAS were required, respectively. In the combined data weed free periods of 27.0 and 22.4 DAS and initial weed infestation of 58.0 and 78.0 DAS were required to cause 25 and 50% reduction in the calyx yield respectively as shown in Figure 3. In 2011 and 2012 also at Samaru, also at

Table 66: Effect of Period of Weed Interference on Weight of Seeds/capsule of Roselle during Wet Seasons of 2011, 2012 and Combined at Samaru and Afaka .

	Weight of seeds/capsule					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	1.65	1.68	1.67	1.62	1.65	1.65
Weed Infested for 6WAS	1.65	1.68	1.67	1.62	1.65	1.64
Weed Infested for 9WAS	1.65	1.67	1.66	1.62	1.64	1.63
Weed Infested for 12WAS	1.64	1.66	1.66	1.62	1.64	1.63
Weed Infested until harvest	1.65	1.68	1.67	1.62	1.64	1.63
Weed Free for 3WAS	1.64	1.67	1.66	1.61	1.64	1.63
Weed Free for 6WAS	1.64	1.68	1.66	1.60	1.66	1.63
Weed Free for 9WAS	1.64	1.68	1.66	1.60	1.66	1.65
Weed Free for 12WAS	1.65	1.68	1.66	1.62	1.67	1.65
Weed Free until harvest	1.65	1.67	1.66	1.61	1.67	1.64
SE$\pm$	0.060	0.061	0.061	0.004	0.005	0.005

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

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Table 67: Effects of Period of Weed Interference on 100-Seed Weight of Roselle during Wet Seasons of 2011,2012 and Combined at Samaru and Afaka.

	100 seed weight					
	Samaru			Afaka		
Treatment	2011	2012	Combined	2011	2012	Combined
Weed Infested for 3WAS	2.74	2.74	2.74	2.30	2.59	2.44
Weed Infested for 6WAS	2.73	2.74	2.74	2.29	2.59	2.44
Weed Infested for 9WAS	2.73	2.73	2.73	2.29	2.58	2.44
Weed Infested for 12WAS	2.73	2.73	2.73	2.29	2.58	2.44
Weed Infested until harvest	2.73	2.74	2.74	2.29	2.58	2.44
Weed Free for 3WAS	2.73	2.74	2.74	2.29	2.59	2.44
Weed Free for 6WAS	2.73	2.73	2.73	2.29	2.59	2.44
Weed Free for 9WAS	2.74	2.74	2.74	2.30	2.61	2.46
Weed Free for 12WAS	2.74	2.74	2.74	2.30	2.60	2.45
Weed Free until harvest	2.74	2.73	2.74	2.31	2.61	2.46
SE$\pm$	0.001	0.001	0.001	0.006	0.006	0.006

WAS: Weeks after sowing.

Means followed by the same letter (s) within a column are not significantly different at P $\leq$ 0.05 level of probability using DMRT.

Samaru the period before interference (PBI) were 26 and 28 days after sowing (DAS) and total period of interference prevention (TPIP) were 43 and 42 DAS, respectively. The critical period interference prevention (CPIP) started at 26and extended until 43 DAS, lasting 17days in 2011. In this location 2012, the CPIP commenced at 28 and extended until 42 DAS, lasting 14 days. In the combined data, PBI was 27 and TPIP 42 DAS. The CPIP started at 27 and extended until 42 DAS, lasting 15days. Critical period of weed interference was between 4 and 6WAS.

In 2011 and 2012 at Afaka, for reduction in potential calyx yield, initial weed free periods of 25.2 and 22.4 DAS and 26.6 and 21.0 DAS were required to cause 25 and 50% reduction in the potential calyx yield, respectively as shown in figures 4 and 5. In the same vein, initial weed infestation of 53.2 and 70 DAS and 57.4 and 84 DAS were required to cause 25 and 50% reduction in the potential calyx yield, respectively.The combined data show that initial weed free periods of 30 and 26 DAS and initial weed infestation period of 43 and 79.0 DAS were required to cause 25 and 50% reduction in the potential calyx yield, respectively as shown in figure 6.

In 2011 and 2012 at Afaka, period before interference (PBI) were 26 and 26 days after sowing (DAS) and total period of interference prevention (TPIP) were 42 and 53 DAS, respectively. The critical period interference prevention (CPIP) started at 30 and extended until 42 DAS, lasting 12days. In 2012 in this location, the (CPIP) commenced at 40 and extended until 53 DAS, lasting 13 days. The combined data (PBI) was 30 and (TPIP) 42 DAS in 2011 and 2012, respectively. The (CPIP) started at 30 and extended until 42 DAS, lasting 12days. Critical period of weed interference was between 4 and 6WAS.

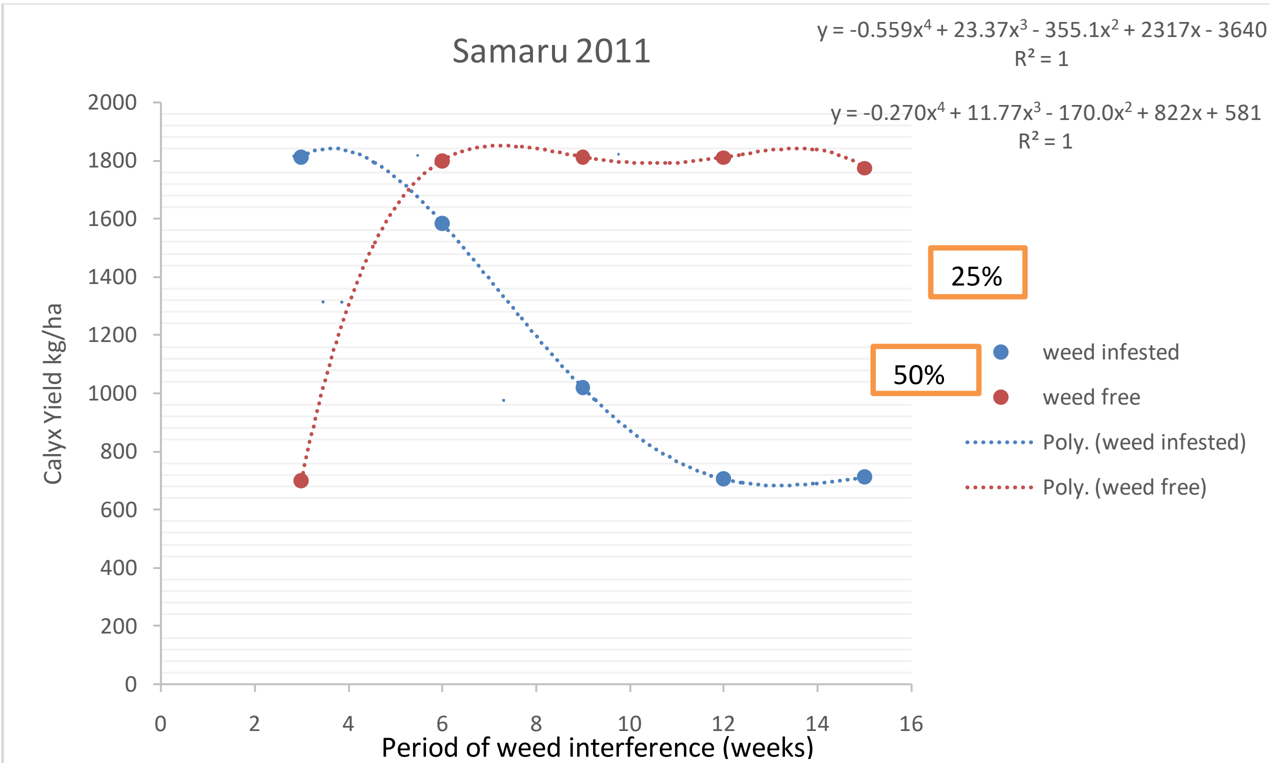


Figure 1: Regression analysis of calyx yield on period of weed interference at Samaru 2011

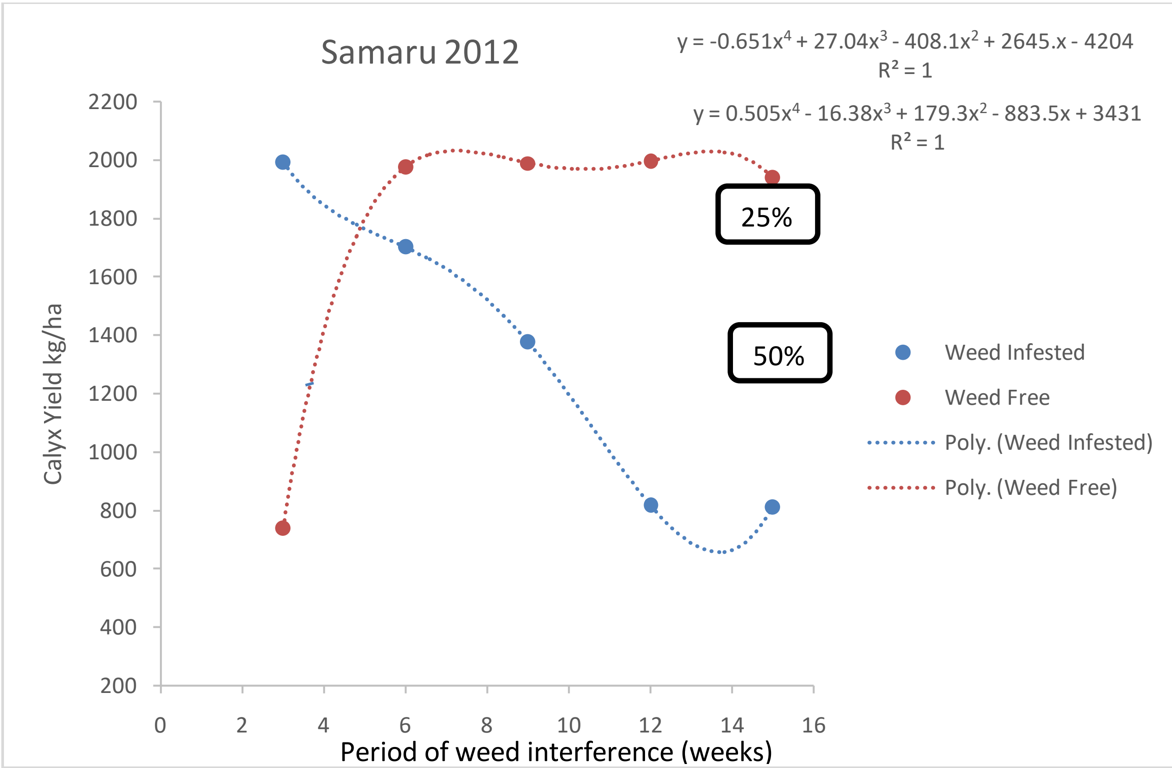


Figure 2: Regression analysis of calyx yield on period of weed interference at Samaru 2012

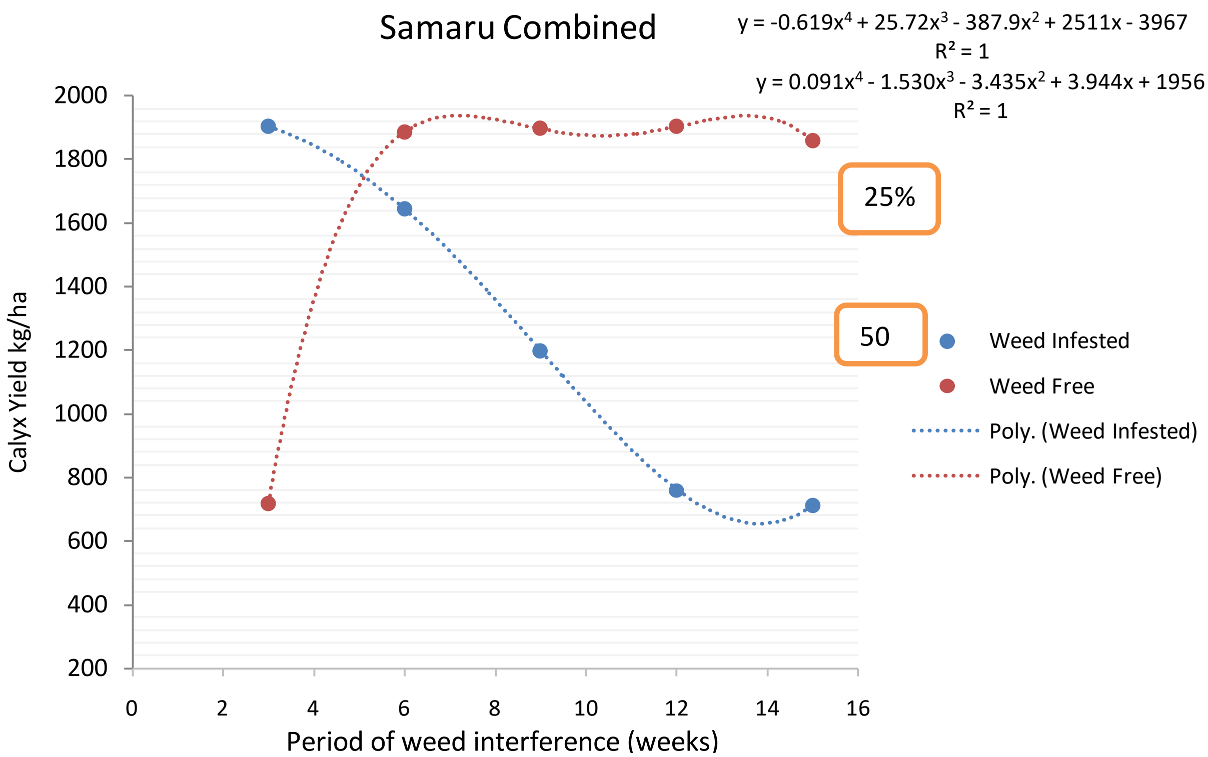


Figure 3: Regression analysis of combined calyx yield on periods of weed interference at Samaru

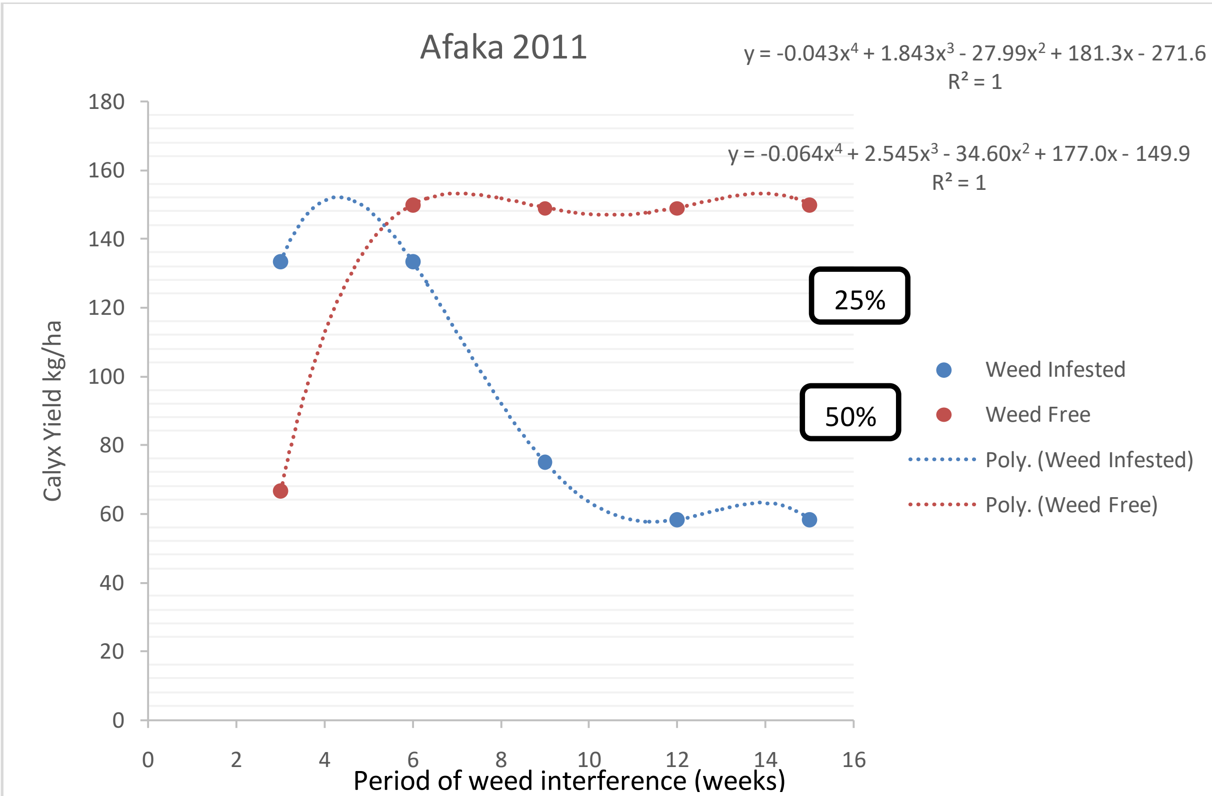


Figure 4: Regression analysis of calyx yield on period of weed interference at Afaka 2011

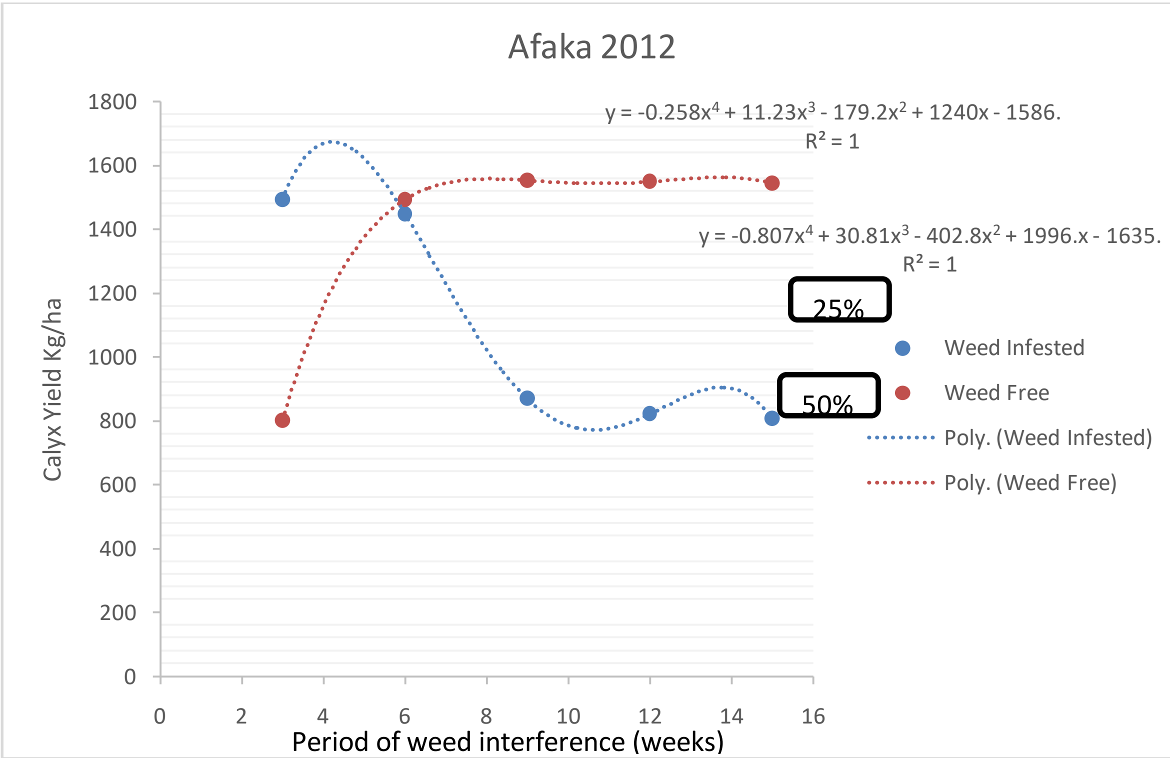


Figure 5: Regression analysis of calyx yield on period of weed interference at Afaka 2012

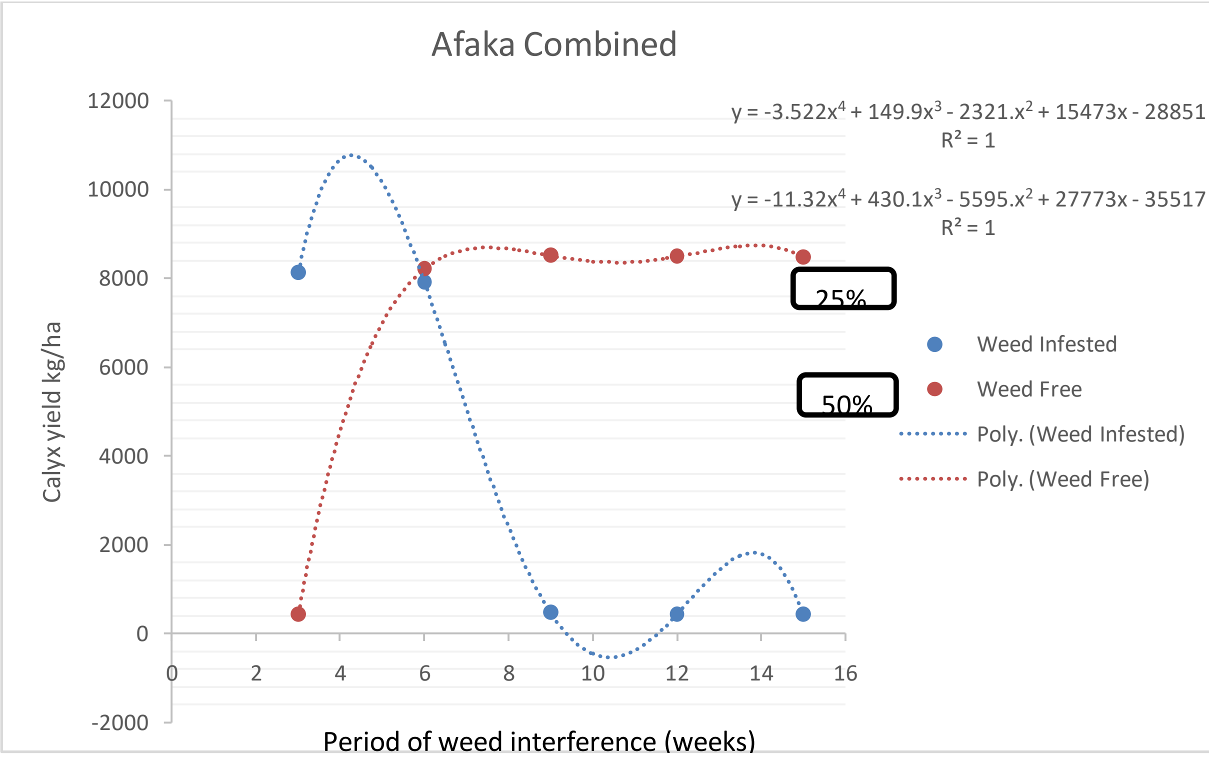


Figure 6: Regression analysis of combined calyx yield on periods of weed interference at Afaka

4.11 Correlations

Matrix of correlation between combined mean yield, yield and growth characters and some weed parameters at Samaru and Afaka are presented in Tables 68 and 69. In the combined matrix analysis at Samaru (Table 68), calyx yield was highly and positively correlated with weed control index, plant height, number of leaves; numbers of primary and secondary branches/plant, and stem girth, each at 9WAS, number of calyx and calyx weight/plant. Calyx yield was also highly but negatively correlated with weed dry weight. Weed dry weight was highly but negatively correlated with weed control index, plant height, number of leaves, number of primary and secondary branches/plant, stem girth, number of calyx/plant and calyx weight/plant.Weed control index was highly and positively correlated with plant height, number of leaves, number of primary and secondary branches/plant, stem girth, number of calyx/plant and calyx weight/plant. Plant height was positively correlated with number of leaves and calyx weight/plant and also highly and positively correlated with number of primary branches/plant and number of calyx/plant. The number of leaves/plant was highly and positively correlated with numbers of primary and secondary branches/plant, stem girth, number of calyx/plant and calyx weight/plant. Number of secondary branches/plant was highly and positively correlated with stem girth, number of calyx/plant and calyx weight/plant. The stem girth was highly and positively correlated with number of calyx/plant and calyx weight/plant. The correlation between number of calyx and calyx weight/plant was strong and positive.

In the same vein at Afaka (Table 69), there was positive and highly significant correlation between calyx yield and plant height, number of leaves and stem girth, each at 9WAS and calyx weight /plant. The weed dry weight was highly and negatively correlated with weed

Table 68: Matrix of correlation coefficients between combined calyx yield of roselle, some growth and yield characters and weed parameters during 2011 and 2012 wet seasons at Samaru

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.926**	1.000								
3	0.932**	-0.990**	1.000							
4	0.828**	-0.589**	0.575**	1.000						
5	0.844**	-0.821**	0.827**	0.422*	1.000					
6	0.737**	-0.764**	0.616**	0.792**	0.874**	1.000				
7	0.855**	-0.837**	0.847**	0.168^{NS}	0.812**	0.116	1.000			
8	0.804**	-0.737**	0.751**	-0.012^{NS}	0.749**	0.042^{NS}	0.918**	1.000		
9	0.944**	-0.972**	0.977**	0.499**	0.867**	0.160^{NS}	0.852**	0.821**	1.000	
10	0.975**	-0.914**	0.919**	0.418*	0.791**	0.151^{NS}	0.772**	0.791**	0.924**	1.000

Df =28, r at 5% =0.361, r at 1% =0.463 *Significant correlation at 5% level of significance ** Highly significant correlation at 1% level of significance NS Not significant

1= Calyx yield/hectare (kg), 2= weed dry matter (9WAS), 3= Weed control index (9WAS), 4= Plant height (9WAS), 5= Number of leaves (9WAS), 6=Number of primary branches/plant (9WAS) 7=Number of secondary branches/plant (9WAS), 8= Stem girth (9WAS) = Number of calyx/plant 10= Calyx weight/plant.

Table 69: Matrix of correlation coefficients between combined calyx yield, of roselle, some growth and yield characters and weed parameters during 2011 and 2012 wet seasons at Afaka.

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.200^{NS}	1.000								
3	-0.306^{NS}	-0.974**	1.000							
4	0.859**	-0.582**	0.628**	1.000						
5	0.674**	-0.791**	0.628**	0.886**	1.000					
6	0.259^{NS}	-0.755**	0.766**	0.562**	0.739**	1.000				
7	-0.118^{NS}	-0.703**	0.692**	0.230^{NS}	0.494**	0.693**	1.000			
8	0.750**	-0.563**	0.678**	0.819**	0.862**	0.644**	0.578**	1.000		
9	0.078^{NS}	-0.304^{NS}	0.321^{NS}	0.133^{NS}	0.266^{NS}	0.229^{NS}	0.298^{NS}	0.055^{NS}	1.000	
10	0.999**	-0.210^{NS}	0.317^{NS}	0.863**	0.681**	0.267^{NS}	0.264^{NS}	0.756**	0.081^{NS}	1.000

Df =28, r at 5% =0.361, r at 1% =0.463 ** Highly significant correlation at 1% level of significance NS Not significant.

1= Calyx yield/hectare (kg), 2= weed dry matter (9WAS), 3= Weed control index (9WAS), 4= Plant height (9WAS), 5= Number of leaves (9WAS), 6=Number of primary branches/plant (9WAS) 7=Number of secondary branches/plant (9WAS), 8= Stem girth (9WAS) = Number of calyx/plant 10= Calyx weight/plant.

control index, plant height, number of leaves, and numbers of primary and secondary branches/plant and stem girth. Weed control index was highly and positively correlated with plant height, number of leaves; numbers of primary and secondary branches/plant and stem girth. Plant height was highly and positively correlated with number of leaves, number of primary branches; stem girth and calyx weight/plant. Number of leaves was highly and positively correlated with number of primary and secondary branches; stem girth and calyx weight/plant. Number of primary branches was highly and positively correlated with number of secondary branches and stem girth. Number of secondary branches was highly and positively correlated with stem girth. Stem girth was highly and positively correlated with calyx weight/plant. The correlation between number of calyx/plant and weight of calyx/plant was non-significant.

4.12 Economic Analysis

4.12.1 Economic analysis of calyx yield as affected by weed control methods during wet seasons of 2011 and 2012 at Samaru and Afaka.

The cost-benefit analyses of calyx yield as affected by weed control methods in 2011 and 2012 at both locations (Samaru and Afaka) are presented in Tables 70, 71, 72 and 73. The fixed cost of producing one hectare of calyx yield in 2011 and 2012 at both locations was ₦25, 000. During the cropping seasons at Samaru, among weed control method, hoe-weeding at 3, 6 and 9WAS gave highest net farm income of ₦96,450 and ₦116,150.00 in 2011 and 2012, respectively with net income of ₦59,150.00 invested in each year, followed by pendimethalin at 1.5 kg a.i/ha with ₦100,000.00and ₦114,000.00 on ₦55,100 invested in each year in 2011 and 2012, respectively. The lowest net farm income was obtained by weedy check and oxadiazon at 2.0 kg a.i /ha of - ₦7, 650.00 on ₦51,100.00 invested and ₦37, 950.00 on N56, 050.00 invested in 2011 and 2012, respectively.

In the same vein at Afaka, hoe-weeding at 3, 6 and 9WAS gave highest net farm income of ₦27, 250.00 and ₦53, 350.00 on ₦59,150.00 on each year invested in 2011 and 2012, respectively. This was followed by pendimethalin at 1.5kg a.i/ha with ₦ 24, 800.00 net farm income on ₦55,100.00 invested in 2011 and metolachlor at 1.5kga.i/ha with ₦53,750.00 on ₦54.050.00 invested in 2012. The lowest was obtained by diuron at 2.5 kg a.i/ ha and the weedy check with - ₦28,850 .00 on ₦28,850.00 invested and ₦10,550.00 on ₦ 50,150 invested in 2011 and 2012, respectively.

4.12.2 Economic analysis of calyx yield as influenced by period of weed Interference during wet seasons of 2011 and 2012 at Samaru and Afaka.

The cost-benefit ratio for the period of weed interference at Samaru and Afaka during wet seasons of 2011 and 2012 are presented in Tables 74 and 7**5.** In 2011 and 2012 at Samaru, the highest net farm incomes of ₦123,800.00 and ₦ 141,500.00 on ₦ 56,100.00 invested in each year were obtained from plots kept weed free for 6WAS in 2011 and 2012, respectively.The least were ₦ 16, 900.00 and ₦20, 700.00 on ₦53,100 invested for each year in 2011 and 2012, respectively by plots kept weed free for 3WAS only. In another development, the highest net farm income of - ₦41,100.00 on ₦ 56,100 invested and ₦96,300 on ₦ 59,100 invested were obtained from plots kept weed free for 6WAS and 9WAS in 2011 and 2012, respectively at Afaka. The least net farm income was obtained from plots kept weed free throughout the crop life-cycle and plots kept weed free for 3WAS only, with ₦54,100.00 and ₦ 27,100.00 on ₦69,100.00 and ₦53,100.00 invested in 2011 and 2012, respectively.

Table 70: Cost benefits analysis of weed control and returns from roselle plant (calyx) at different weed control methods during wet season of 2011, at Samaru.

S/N	Treatment	Rates (kg a.i/ha)	Calyx kg/ha	Revenue 2011 (~~N~~)	Fixed cost (~~N~~)	Variable Cost (~~N~~)	Total cost (~~N~~))	Net income (~~N~~)
1	Oxadiazon	1.5	825.	82,500	25,000	27,800	52,800	29,700
2	Oxadiazon	2.0	725	72,500	25,000	28,050	53,050	19,450
3	Diuron	2.0	628	62,800	25,000	20,000	45,000	17,800
4	Diuron	2.5	424	42,400	25,000	21,100	46,100	-3,700
5	Metolachlor	1.5	1479	147,900	25,000	29,050	54,050	93,850
6	Metolachlor	2.0	1467	146,700	25,000	30,150	55,150	91,550
7	Butachlor	1.5	1469	146,900	25,000	29,100	54,100	92,800
8	Butachlor	2.0	1458	145,800	25,000	30,150	55,150	90,650
9	Pendimethalin	1.5	1551	155,100	25,000	30,100	55,100	100,000
10	Pendimethalin	2.0	1532	153,200	25,000	31,150	56,150	97,050
11	HW @4WAS	-	529	52,900	25,000	28,150	53,150	-250
12	HW @ 3 and 6 WAS	-	1437	143,700	25,000	31,150	56,150	87,550
13	HW @ 3, 6 and 9 WAS	-	1556	155,600	25,000	34,150	59,150	96,450
14	Weedy check	-	425	42,500	25,000	25,150	50,150	-7,650

Source of prices of farm operations: Institute for Agricultural Research Samaru, Zaria.

Calculation of total revenue is based on N100/kg, the prevailing price of roselle in Samaru

Table 71: Cost benefits analysis of weed control and returns from roselle plant (calyx) at different weed control methods during wet season of 2012, at Samaru**.**

S/N	Treatment	Rates (kg a.i/ha)	Calyx kg/ha	Revenue (₦)	Fixed cost (₦)	Variable cost (₦)	Total cost (₦)	Net income (₦)
1	Oxadiazon	1.5	1459	145,900	25,000	30,800	55,800	90,100
2	Oxadiazon	2.0	940	94,000	25,000	31,050	56,050	37, 950
3	Diuron	2.0	1355	135,500	25,000	27,100	52,100	83,400
4	Diuron	2.5	1343	134,300	25,000	28,000	53,000	81, 300
5	Metolachlor	1.5	1535	153,500	25,000	29,050	54,050	99,450
6	Metolachlor	2.0	1584	158,400	25,000	30,150	55,150	103, 250
7	Butachlor	1.5	1566	156,600	25,000	29,100	54,100	102,500
8	Butachlor	2.0	1574	157,400	25,000	30,150	55,150	102,300
9	Pendimethalin	1.5	1691	169,100	25,000	30,100	55,100	114,000
10	Pendimethalin	2.0	1695	169,500	25,000	31,150	56,150	113,350
11	HW @4WAS	-	1318	131,800	25,000	28,150	53,150	78,650
12	HW @ 3 and 6 WAS	-	1553	155,300	25,000	31,150	56,150	99,150
13	HW @ 3, 6 and 9 WAS	-	1753	175,300	25,000	34,150	59,150	116,150
14	Weedy check	-	1323	132,300	25,000	25,150	50,150	82,150

Source of prices of farm operations: Institute For Agricultural Research Samaru, Zaria.

Calculation of total revenue is based on N100/kg, the prevailing price of roselle in Samaru Market.

Table 72: Cost benefits analysis of weed control and returns from roselle plant (calyx) at different weed control methods during wet season of 2011, at Afaka.

S/N	Treatment	Rates (kg a.i/ha)	Calyx (kg/ha	Revenue (₦)	Fixed cost (₦)	Variable cost (₦)	Total cost (₦)	Net income (₦)
1	Oxadiazon	1.5	617	61700	25,000	25,800	50,800	10, 900
2	Oxadiazon	2.0	537	53700	25,000	28,050	53,050	650
3	Diuron	2.0	0.00	0	25,000	3,100	28,100	-28,100
4	Diuron	2.5	0.00	0	25,000	3,850	28,850	-28,850
5	Metolachlor	1.5	727	72700	25,000	26,000	54,050	18,650
6	Metolachlor	2.0	666	66600	25,000	26,100	55,150	11,450
7	Butachlor	1.5	647	64700	25,000	26,050	54,100	10,600
8	Butachlor	2.0	620	62000	25,000	26,150	55,150	6,850
9	Pendimethalin	1.5	799	79900	25,000	26,100	55,100	24,800
10	Pendimethalin	2.0	784	78400	25,000	26,150	56,150	22,250
11	HW @4WAS	-	411	41100	25,000	26,150	53,150	-12,050
12	HW @ 3 and 6 WAS	-	747	74700	25,000	27,150	56,150	18,550
13	HW@3,6 and 9 WAS	-	864	86400	25,000	28,150	59,150	27,250
14	Weedy check	-	351	35100	25,000	25,150	50,150	-15,050

Source of prices of farm operations: Kaduna State Agriculture Development Program (KADP), Afaka , Kaduna.

Calculation of total revenue is based on N100/kg, the prevailing price of roselle in Afaka Mando/Kawo Market, Kaduna

Table 73: Cost benefits analysis of weed control and returns from roselle plant (calyx) at different weed control methods during wet season of 2012 , at Afaka.

S/N	Treatment	Rates (kg a.i/ha)	Calyx kg/ha	Revenue 2012 (₦)	Fixed cost (₦)	Variable cost (₦)	Total cost (₦)	Net income (₦)
1	Oxadiazon	1.5	960	96,000	25,000	30,800	55,800	45,200
2	Oxadiazon	2.0	840	84,000	25,000	31,050	56,050	27,950
3	Diuron	2.0	696	69,600	25,000	27,100	52,100	17,500
4	Diuron	2.5	693	69,300	25,000	28,000	53,000	16,300
5	Metolachlor	1.5	1078	107,800	25,000	29,050	54,050	53,750
6	Metolachlor	2.0	1031	103,100	25,000	30,150	55,150	47,950
7	Butachlor	1.5	1008	100,800	25,000	29,100	541,00	46,700
8	Butachlor	2.0	942	94,200	25,000	30,150	55,150	39,050
9	Pendimethalin	1.5	1075	107,500	25,000	30,100	55,100	52,400
10	Pendimethalin	2.0	1064	106,400	25,000	31,150	56,150	50,250
11	HW @4WAS	-	865	86,500	25,000	28,150	53,150	33,350
12	HW @ 3 and 6 WAS	-	1027	102,700	25,000	31,150	56,150	46,550
13	HW@3,6 and 9 WAS	-	1125	112,500	25,000	34,150	59,150	53,350
14	Weedy check	-	607	60,700	25,000	25,150	50,150	10,550

Source of prices of farm operations: Kaduna State Agriculture Development Program (KADP), Afaka , Kaduna.

Calculation of total revenue is based on N100/kg, the prevailing price of roselle in Afaka Mando/Kawo Market,Kadun

Table 74: Cost benefits analysis on effects of period of weed interference and returns from the yield of roselle plant (calyx) during wet seasons of 2011 and 2012 at Samaru.

S/N	Treatment	Calyx Kg/ha 2011	Revenue 2011 (₦)	Calyx Kg/ha 2012	Revenue 2012 (₦)	Fixed cost (₦)	Variable cost (₦)	Total cost (₦)	Net income (₦) 2011	Net income (₦) 2012
1	WI 3	1813	181,300	1993	199,300	25,000	40,100	65,100	116, 200	134,200
2	WI 6	1586	158,600	1702	170,200	25,000	36,100	61,100	97, 500	109,100
3	WI 9	1019	101,900	1377	137,700	25,000	32,100	57,100	44, 800	80,600
4	WI 12	705	70,500	819	81,900	25,000	28,100	53,100	17, 400	28,800
5	WI T	711	71,100	811	81,100	25,000	25,100	51,100	20,000	30,000
6	WF 3	700	70,000	738	73,800	25,000	28,100	53,100	16,900	20,700
7	WF 6	1799	179,900	1976	197,600	25,000	31,100	56,100	123,800	141,500
8	WF 9	1813	181,300	1991	199,100	25,000	34,100	59,100	122,200	140,000
9	WF 12	1811	181,100	1997	199,700	25,000	37,100	62,100	119,000	137,600
10	WF T	1775	177,500	1941	194,100	25,000	44,100	69,100	108,400	125,000

Source of prices of farm operations: Institute For Agricultural Research Samaru, Zaria.

Calculation of total revenue is based on N100/ kg the prevailing price of Roselle in Samaru Market.

WI3=Weed Infested for 3WAS, WI6= Weed Infested for 6WAS,WI9=Weed Infested for 9WAS,W12=Weed Infested for 12WAS, WIT=Weed Infested Throughout, WF3= Weed free for 3WAS, WF6=Weed free for 6WAS, WF9=Weed free for 9WAS, WF12=Weed free for 12WAS, WFT=Weed free Throughout, WAS=Weeks after sowing

Table 75: Cost benefits analysis on effects of period of weed interference and returns from the yield of roselle plant (calyx) during wet seasons of 2011 and 2012 at Afaka.

S/No	Treatment	Calyx kg/ha 2011	Revenue 2011 (₦)	Calyx kg/ha 2012	Revenue 2012 (₦)	Fixed cost (₦)	Variable cost (₦)	Total cost (₦)	Net income (₦) 2011	Net income (₦) 2012
1	WI 3	133	13,300	1494	149,400	25,000	40,100	65,100	-51,800	84,300
2	WI 6	133	13,300	1450	145,000	25,000	36,100	61,100	-47,800	83,900
3	WI 9	75	7,500	869	86,900	25,000	32,100	57,100	-49,600	29,800
4	WI 12	58	5,800	821	82,100	25,000	28,100	53,100	-47,300	29,000
5	WI T	58	5,800	806	80,600	25,000	25,100	51,100	-45,300	29,500
6	WF 3	66	6,600	802	80,200	25,000	28,100	53,100	-46,500	27,100
7	WF 6	150	15,000	1493	149,300	25,000	31,100	56,100	-41,100	93,200
8	WF 9	149	14,900	1554	155,400	25,000	34,100	59,100	-44,200	96, 300
9	WF 12	149	14,900	1550	155,000	25,000	37,100	62,100	-47,200	93,400
10	WF T	150.	15,000	1544	154,400	25,000	44,100	69,100	-54,100	85,300

Source of prices of farm operations: Kaduna State Agriculture Development Program (KADP).Afaka, Kaduna.

Calculation of total revenue is based on N100/kg , the prevailing price of Roselle in Afaka Mando/Kawo Kaduna.

WI3=Weed Infested for 3WAS, WI6= Weed Infested for 6WAS,WI9=Weed Infested for 9WAS,W12=Weed Infested for 12WAS, WIT=Weed Infested Throughout, WF3= Weed free for 3WAS, WF6=Weed free for 6WAS, WF9=Weed free for 9WAS, WF12=Weed free for 12WAS, WFT=Weed free Throughout, WAS=Weeks after sowing

4.13 Proximate Analysis.

4.13.1 Effects of herbicides on nutritional quality of calyx in 2011 and 2012 at Samaru and Afaka.

The results obtained from proximate analysis on nutritional and mineral composition of roselle plant (calyx) as a result of herbicides applied in years of study at the two locations are presented in Tables 76 and 77also in Plate 1 and II. The nutritional qualty analyzed comprises of protein, fibre, ash, ascorbic acid, vitamin B2, Vitamin B1, vitamin D and vitamin B complex. The mineral composition includes Iron, Calcium, Magnesium and Phosphorus. The result shows appreciable values of nutritional and essential mineral composition present in the calyx which were similar when compared with control (weedy check).

Table 76 : Effects of herbicides on nutritional quality of calyx in 2011 and 2012 at Samaru.

Treatments	Rates (kga.i/ha)	Protein %	Fibre %	Ash %	Iron %	Calcium %	Ascorbic Acid (mg)	Vitamin B2 (mg)	Vitamin B1 (mg)	Vitamin D (mg)	Vitamin B complex (mg)
Oxadiazon	1.5	11.06	4.18	6.23	58.0	64.0	11.03	0.55	0.03	2.77	2.67
Oxadiazon	2.0	11.06	4.18	6.23	58.0	64.0	11.04	0.55	0.03	2.77	2.66
Diuron	2.0	11.12	4.08	7.05	56.85	65.0	15.16	0.55	0.03	3.49	2.91
Diuron	2.5	11.14	4.08	7.05	56.9	65.0	15.16	0.55	0.03	3.45	2.92
Metoolachlor	1.5	10.91	4.07	6.48	56.5	63.0	15.46	0.55	0.03	3.92	2.85
Metolachlor	2.0	10.95	4.07	6.49	56.5	63.0	15.47	0.55	0.03	3.91	2.84
Butachlor	1.5	10.88	4.14	6.85	57.8	64.0	14.96	0.55	0.03	4.00	2.91
Butachlor	2.0	10.87	4.14	6.84	57.8	64.0	14.95	0.55	0.03	4.00	2.91
Pendimethalin	1.5	11.02	4.20	6.47	57.5	64.0	14.02	0.56	0.04	4.26	2.85
Pendimethalin	2.0	11.12	4.20	6.47	57.6	64.0	15.02	0.56	0.04	4.26	2.85
Weedy Check		11.07	4.20	7.04	57.0	64.0	14.58	0.56	0.04	3.57	2.88

Source: Department of Soil Science Ahmadu BelloUniversity, Zaria.

Department of Animal science Ahmadu BelloUniversity, Zaria.

National Research Institute of Chemical Technology (NARICT), Zaria.

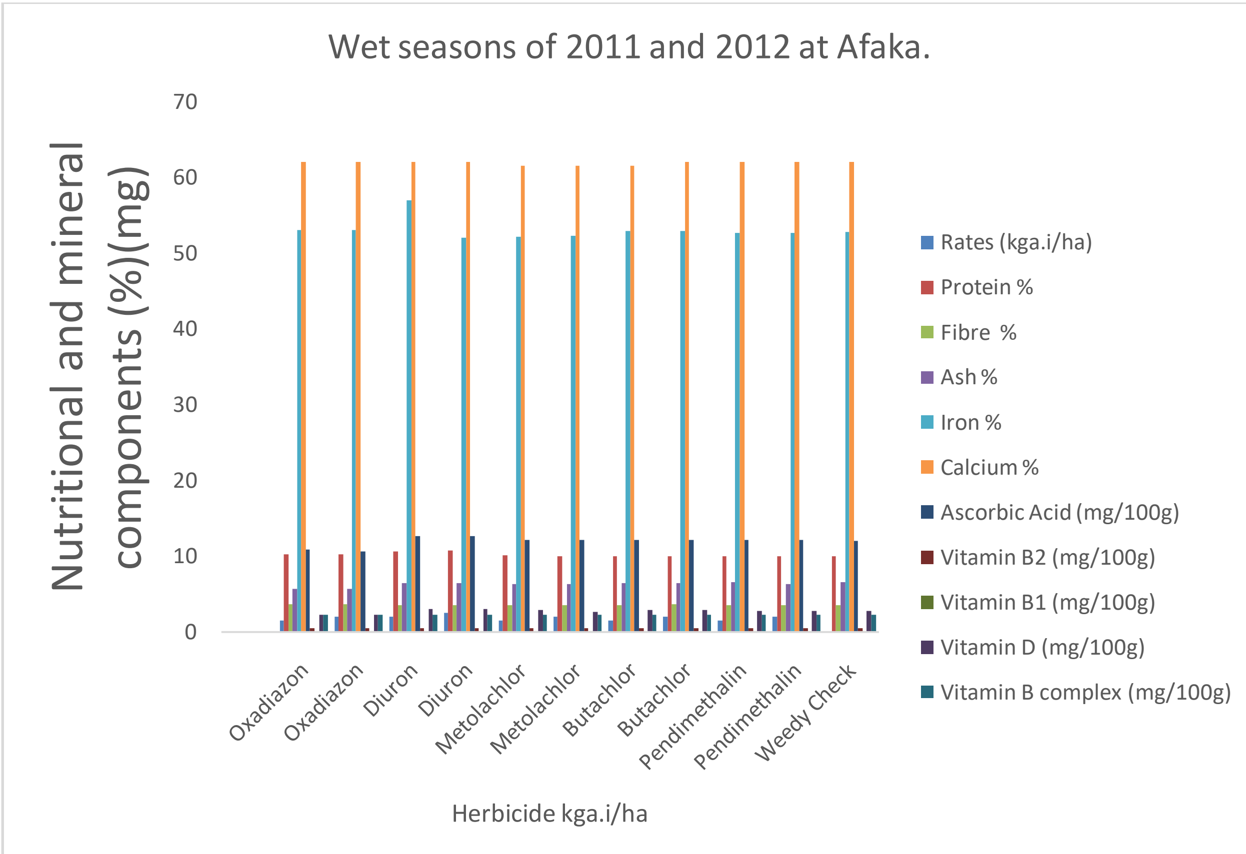
Table 77: Effects of herbicides on nutritional quality of calyx in 2011 and 2012 at Afaka.

Treatments	Rates (kga.i/ha)	Protein %	Fibre %	Ash %	Iron %	Calcium %	Ascorbic Acid (mg)	Vitamin B2 (mg)	Vitamin B1 (mg)	Vitamin D (mg)	Vitamin B complex (mg)
Oxadiazon	1.5	10.25	3.69	5.68	53.0	62.0	10.83	0.52	0.03	2.30	2.24
Oxadiazon	2.0	10.25	3.69	5.69	53.0	62.0	10.61	0.52	0.03	2.30	2.24
Diuron	2.0	10.65	3.50	6.43	57.0	62.0	12.68	0.54	0.03	3.00	2.32
Diuron	2.5	10.72	3.50	6.45	52.0	62.0	12.68	0.54	0.03	3.00	2.34
Metolachlor	1.5	10.08	3.55	6.35	52.2	61.5	12.12	0.52	0.03	2.90	2.34
Metolachlor	2.0	10.05	3.55	6.35	52.25	61.5	12.11	0.52	0.03	2.70	2.34
Butachlor	1.5	10.04	3.60	6.43	52.9	61.5	12.21	0.51	0.03	2.96	2.32
Butachlor	2.0	10.01	3.63	6.43	52.9	62.0	12.21	0.51	0.03	2.96	2.32
Pendimethalin	1.5	10.01	3.58	6.53	52.7	62.0	12.21	0.52	0.03	2.77	2.33
Pendimethalin	2.0	10.01	3.55	6.35	52.7	62.0	12.21	0.52	0.03	2.77	2.33
Weedy Check		10.00	3.55	6.56	52.75	62.0	12.0	0.52	0.03	2.76	2.33

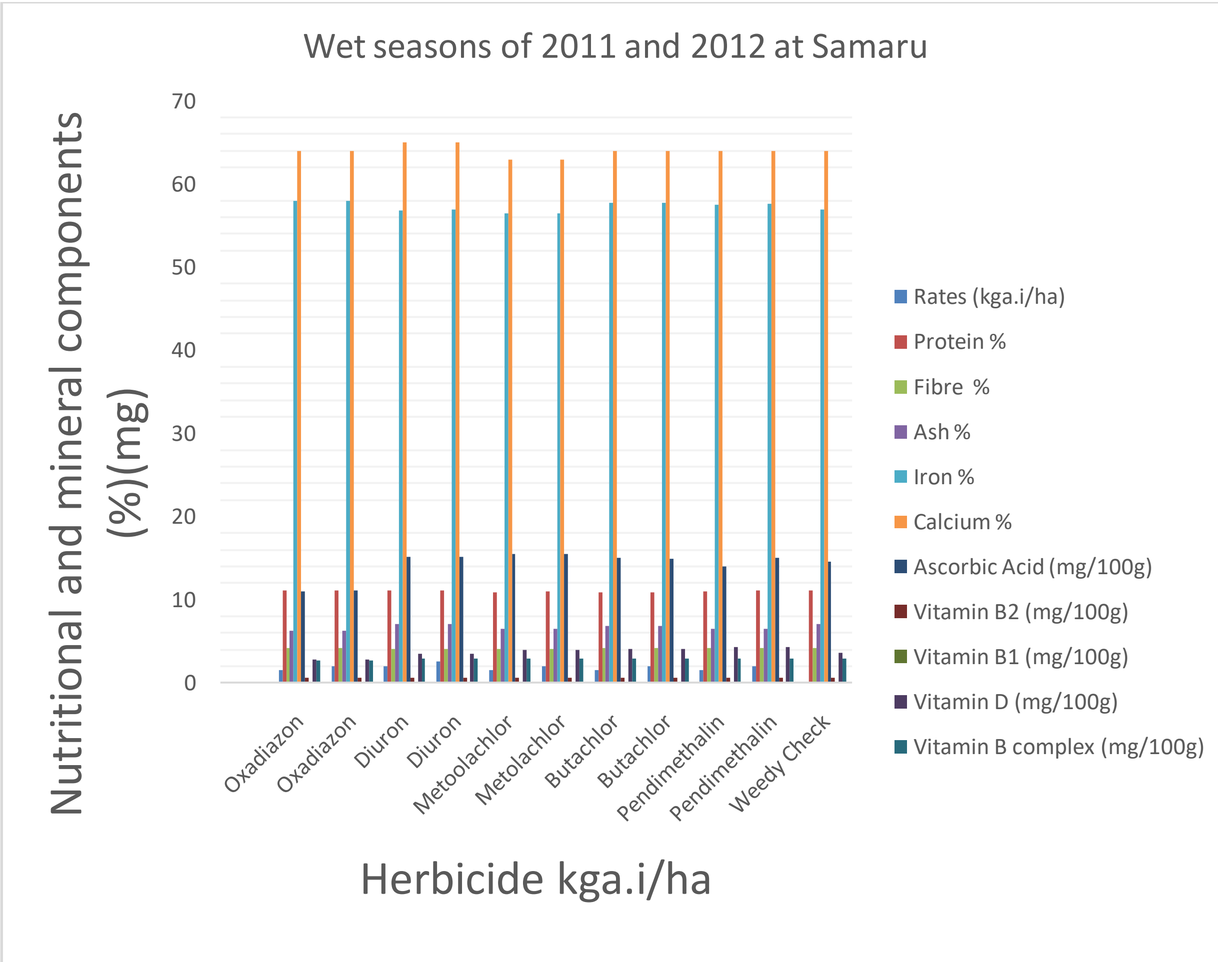
Source: Department of Soil Science ABU Zaria.

Department of Animal Science ABU Zaria.

National Research Institute of Chemical Technology (NARICT) Zaria



Wet seasons of 2011 and 2012 at Afaka.
Nutritional and mineral components (%)(mg)
70
60
50
40
30
20
10
0
Oxadiazon
Oxadiazon
Diuron
Diuron
Metolachlor
Metolachlor
Butachlor
Butachlor
Pendimethalin
Pendimethalin
Weedy Check
Herbicide kga.i/ha
Rates (kga.i/ha)
Protein %
Fibre %
Ash %
Iron %
Calcium %
Ascorbic Acid (mg/100g)
Vitamin B2 (mg/100g)
Vitamin B1 (mg/100g)
Vitamin D (mg/100g)
Vitamin B complex (mg/100g)


Wet seasons of 2011 and 2012 at Samaru
Nutritional and mineral components (%)(mg)
70
60
50
40
30
20
10
0
Oxadiazon
Oxadiazon
Diuron
Diuron
Metoolachlor
Metolachlor
Butachlor
Butachlor
Pendimethalin
Pendimethalin
Weedy Check
Herbicide kga.i/ha
Rates (kga.i/ha)
Protein %
Fibre %
Ash %
Iron %
Calcium %
Ascorbic Acid (mg/100g)
Vitamin B2 (mg/100g)
Vitamin B1 (mg/100g)
Vitamin D (mg/100g)
Vitamin B complex (mg/100g)

CHAPTER FIVE

5.0 DISCUSSION

5.1 General Performance of the Crop

`Plant growth and yield characters of roselle responded to weed control methods and period of weed interferenceperiod.The overall performance of roselle as demonstrated by growth and yield character was better in 2012 than 2011in both experiments and locations.This could be attributed to more favourable amount and distribution of rainfall in 2012 than 2011(Appendices I-IV). The adequate soil P in the experimental site in 2012 at both locations which might have enhanced rapid growth required to suppress the weeds in 2012 than 2011 (Tables 1 and 2) contributed to the higher yield obtained. Also, phytotoxic effect exhibited by diuron on the test crop (roselle) in experiment 1 and infestation of parasitic weed (*Cuscuta compestris)* at both locations in 2011 could be responsible for lower performance of the crop.

5.2 Effect of Weed Control Methods

5.2.1 Effect of weed control methods on weeds.

Weeds cause serious problem in crop production, especially during the initial stages of crop growth, and when crop growth is slower than that of the weeds with which they are associated (Akobundu, 1987). Young crop plants are not very competitive; therefore even moderate level of weed infestation could reduce crop establishment and productivity (Das 2011).Weed suppression promoted crop growth and resulted in increase in dry matter production with corresponding increase in number of leaves. Crop plants ultimately depend on green leaf area for dry matter accumulation as the leaf intercepts solar radiation which facilitates photosynthesis.The production, expansion and survival of green leaves are important determinants of crop production (David *et al.*,2009).

A total of sixteen weed species were identified in the trials at both locations of study.The predominant weed species identified were grasses, broadleaves and sedges (Table 3 and 4) and have been reported to be commonly associated with upland ecologies (Akobundu,1987; Singh *et al*., 2001). The diversity in weed flora could be attributed to the level of disturbance of field (tillage/cultivation), especially at Samaru, and changes made in the agronomic practices towards raising crops as indicated by Das (2011). Koch *et al*. (1982) reported that intensively cropped areas usually have 10-15 weed species compared to 50 or more in extensively cropped areas. This qualifies the field used as being intensively cropped.

The results of this research indicated that application of pre-emergence herbicides including oxadiazon, diuron, metolachlor, butachlor and pendimethalin in 2011 and 2012 at Samaru and Afaka exhibited weed growth reduction as reflected on weed cover score and weed dry weight, when compared to the weedy check with greater values, confirming herbicides effectiveness in delaying the emergence and growth of weeds. This might have reduced weed competition against the crop plants and therefore promoted good growth and yield of roselle.This showed that the herbicides controlled weeds during the critical period of weed competition since, with the exception of diuron, all the treatments enhanced calyx yield. These demonstrated broad spectrum weed control, which involved grasses, broadleaves and sedges that were found in the two locations. A better weed control might have in turn enhanced growth characters as indicated in the record of plant height, numbers of leaves, stem girth, number of primary, secondary and tertiary branches of roselle plants compared to the weedy check. Similar results were reported by Adekpe and Adigun (2000), where oxadiazon at 1.0 and 1.5k g a.i /ha and pendimethalin at 1.0 and 1.5 kg a.i /ha suppressed weed growth and enhanced the yield of roselle. Adigun (2009) reported effective weed control of roselle by metolachlor plus metobromuron at 1.0+1.0 kg a.i /ha, while Mohammed *et al.* (2012) also observed that pendimethalin at 1.5 kg a.i /ha could provide alternative to two hoe-weeding for good vegetative growth in roselle. The results are in line with the findings of Awan (1990), Chandi *et al.*(1994), Nobrega *et al.*(1998), Rout and Satarapathy(1998), Ali *et al.*(2005), Mahar *et al.*(2007), Askew *et al.*(2012) and Muhammad *et al.* (2013), who suggested that the use of chemical method of weed control could enhance cotton productivity.Weed suppression by metolachlor has also been reported by Lagoke *et al.* (1981a) on okra, Kuchinda *et al.* (1991) and Kuchinda (1998) on kenaf. Akobundu (1987) reported that oxadiazon causes foliar burn on contact with susceptible weeds. Oxadiazon has also been reported to effectively suppress and control the growth of weeds when applied to the crop at appropriate rates (Ojenomoh, 2000; Ishaya, 2004). Metolachlor and butachlor inhibit root and shoot growth by inhibiting photosynthesis, protein and lipid syntheses. Pendimethalin exerts its herbicidal action by inhibiting both root and shoot growth and development by interfering with cell-division (Huffman and Comper, 1978; Das, 2011). It also slow several biochemical processes such as photosynthesis and RNA and lipid synthesis and oxidative phosphorylation (Robert, 1982). Diuron acts by binding to the D1 protein in photosystem II, which blocks photosynthetic electron flow and this in turns limits the fixation of carbon dioxide in plant (Das, 2011).

The reduced weed dry weight experienced with application of oxadiazon at 1.5 and 2.0 kg a.i /ha, diuron at 2.0 and 2.5 kg a.i /ha, metolachlor at 1.5 and 2.0 kg a.i /ha, butachlor at 1.5and 2.0 kg a.i /ha and pendimethalin at 1.5 and 2.0 kg a.i /ha may be an indication of effectiveness of these herbicides in controlling weeds. Panwar *et al.* (2001) also reported that application pendimethalin at 1.0 kg a.i /ha significantly reduced weed dry weight of weeds over unchecked weed growth.The present findings are in line with reports by Chandi *et al*. (1993) and Awan (1990) on cotton; Ojenomoh (2000) on rice; Khan and Khan (2003) and Anjum *et al*.(2007) on rainfed cotton, Sodangi and Bark (2007) on irrigated cotton, Imoloame *et al*. (2010) on sesame, Naseer-ud-Din*et al*.(2011) on wheat, Shahzad *et al*.(2012) on wheat, Muhammad *et al*.(2013) on cotton and Shivalingappa *et al*. (2014) on garden egg.The herbicide treatments were also compared to hoe-weeding and these corrobated the findings reported by Adekpe and Adigun (2000); Adigun (2009) and Mohammed *et al*., (2012), who had excellent weed control as a result of metolachlor, oxadiazon and pendimethalin on roselle.

The most effective herbicide treatment for weed control among those evaluated was diuron at 2.5 kg a.i /ha, which exhibited maximum reduction of weeds. This might be attributed to its ability in providing season long effective weed control than others, its possible persistence in the soil and also its effectiveness on the broad-leaves weeds than grasses, which were also common in the two study areas (Akobundu, 1987; Kuchinda, 2012). Diuron applied at 2.5 kg a.i/ha resulted in significantly lower weed cover score and weed dry weight, which were less than by the other rates of herbicides evaluated and two hoe-weedings in both locations. It consistently resulted in higher weed control index than the other herbicide treatments, which were comparable to two hoe-weedings treatment in each sampling period. This corrobates the findings of Ibrahim *et al*. (2008), who reported that pre-emergence application of diuron at 0.960kg a.i /ha gave excellent broad-leaves weed control on sesame in Egypt. The authors further suggested that diuron could be used as alternative to two hoe-weedings at 3 and 6WAS. Similarly, higher herbicide efficiency index was obtained with pendimethalin at 2.0 kg a.i/ha in 2011and 2012 at Samaru and 2011 at Afaka and metolachlor at 1.5 kg a.i /ha in 2012 at Afaka and the values were

212.63, 219.51, 82.81 and 65.25, respectively, compared to other treatments in the trials. This could be as a result of tolerance of roselle to these herbicides at the given rates and the herbicides ability to effectively control weeds at critical period, which resulted in good crop yield. Similar findings on these herbicides have been reported by Adekpe and Adigun (2000) that application of pendimethalin at 1.0 and1.5 kg a.i /ha resulted in higher vegetative growth and more fruit yield of roselle. Mohammed *et al.* (2012) also reported that pendimethalin at 1.5 kg a.i /ha gave more leafy yield of roselle and could be used as alternative to two-hoe weedings. The use of pendimethalin to control weeds in cotton has also been reported by several workers including Nobrega *et al*. (1998), Rout and Satapathy (1998), Hiremath and Rao (2001), Panwar *et al*. (2001) and Mahar *et al*. (2007).

However, all the herbicides applied did not give season long weed control on roselle due to the diversity of weeds on the experimental site which resulted in weed resurgence at 9 and12WAS. The higher weed cover score and weed dry weight observed on plots treated with pendimethalin, metolachlor and butachlor each at 1.5 and 2.0 kg a.i /ha at 9 and 12WAS in the years of study at both locations, might be as a result of short duration of activities of these herbicides in the soil and progressive loss of potency over time, resulting in poor weed control at the later stage of crop growth.The volatile nature of dinitroaniline such as pendimethalin could account for duration of the herbicide which may vary with temperature and moisture condition of soil (Akobundu 1987; Rao 2004).The proliferation of late emerging weeds, especially broad-leaves weeds, grasses and sedges, including *Crotalaria juncea, Ageratum conyzoides, Rottboelia cochinchinensis, Cyperus rotundus and Cyperus iria* on which pendimethalin, butachlor and metolachlor were not effective, could possibly a result of limited foliar absorption of those herbicides (Das, 2011).

5.2.2 Effects of weed control method on growth of roselle

Dependance on traditional manual methods of weed control is most labour intensive and unpracticable in modern agricultural production (Mahar *et al*., 2007). Suppression of weeds from crop fields by adopting various measures and maintaining favourable crop enviroment integrated with chemical weed control is the most effective approach (Zhang, 2003). Most farmers, practice interculturing to eradicate the weeds, but this practice is not applicable during the wet season due to wet condition in the soil which does not permit mechanical weeding. Under such a situation, the use of herbicide is a better option to check weeds (Ansari *et al*., 2003).

The positive effect of all the pre-emergence herbicides in 2011 and 2012 at Samaru and Afaka, except with diuron at 2.0 and 2.5 kg a.i /ha and oxadiazon at 1.5 and 2.0 kg a.i /ha in 2011 at both locations, which had phytotoxic effect on roselle, indicates that these herbicides controlled the weeds throughout the critical period of weed competition. Fageiry (2008) reported oxadiazon and its tank with diuron were considered to be too damaging for recommendation to kenaf growers. The results indicated that weeding the crop at 3and 6WAS resulted in comparable vegetative growth characters of roselle to those of the herbicide control treatments.Katung (1997) and Kuchinda (1998) have estimated the critical period for weed competition for kenaf to be between 3 and 6WAS. All the herbicide treatments gave significantly higher percentage seedling emergence score and were not phytotoxic thereby produced more vigorous plants with the exception of treatments with diuron and oxadiazon in 2011 at both locations. The observed significant reduction in percentage seedling emergence score, higher crop injury and low crop vigour exihibited by diuron and oxadiazon could be due to poor crop tolerance to the herbicides by the roselle, particularly during the seedling stage. This phytotoxicity could be as a result of moist soil in experimental site following a heavy rainfall that fell some hours after application, which might have left diuron to be in soil solution and competed for adsorption site on crop roots as reported by El-Amin (1991) and Das (2011).

The best weed control treatments were application of pendimethalin at 1.5 and 2.0 kg a.i/ha, metolachlor at 1.5 kg a.i/ha and hoe-weeding at 3, 6 and 9WAS, which gave much more effective weed control, produced more number of leaves, taller plants, thicker stems, more number of primary, secondary and tertiary branches, than the other treatments. Among the treatments, herbicide that were very effective in delaying weed emergence with consequent reduction in weed competition in roselle and in turn promoted rapid crop growth included pendimethalin, metolachlor, and butachlor each at 1.5 and 2.0 kg a.i /ha. Some of these promising herbicides in this study have also been reported to give good weed control in roselle (Adekpe and Adigun 2000; Adigun 2009 and Mohammed *et al.*, 2012). These herbicides are able to keep the crop weed free in the early stages of growth, reduced hoe-weeding by 50% and resulted in higher growth of roselle plants, comparable to two hoe-weedings at 3 and 6WAS. Lagoke *et al.* (1981b) reported that metolachlor gave selective weed control and resulted in better development of kenaf than the hoe-weeded control. Adekpe and Adigun (2000), Adigun (2009) and Mohammed *et al.* (2012) have also reported that metolachlor plus metobromuron at 1.0+1.0 kg a.i /ha and pendimethalin at 1.0 and 1.5 kg a.i /ha gave selective weed control and better development of roselle than the control.

The herbicidal treatments and two hoe-weeding significantly increased growth characters at both locations compared to the weedy check due to good weed control. This could have accounted for the ability of roselle plants to intercept more solar energy and got more nutrients for better growth and development. It was reported that pre-emergence herbicides kill weeds, and in so doing, they play a role of providing mulch of dead plant material which helps to conserve moisture and add nutrients to the soil (Das, 2011). The higher growth characters of roselle obtained as a result of herbicides treatments in years of study at both locations except diuron at the two given rates in 2011 at both locations than the weedy check could be an indication that the herbicides treatments controlled the weeds in roselle, which in turn resulted in reduced competition for the growth resources with the crop, thus permitting a better growth and development of the roselle crop. The results obtained corrobate with the findingsof Adekpe and Adigun (2000) whoreported that application of pendimethalin at 1.0 and 1.5 kg a.i /ha and metobromuron plus metolachlor at 2.0 kg a.i /ha gave effective weed control in roselle. Similar report was made by Adigun (2009) in roselle on metolachlor plus metobromuron at 1.0 plus 1.0 kg a.i/ha. Mohammed *et al*. (2012) also reported similar trend with pendimethalin at 1.0 and 1.5 kg a.i /ha on the same crop. Several other workers gave similar report: Haruna *et al.* (2012) on the use metolachlor and pendimethalin at 1.0 kg a.i /ha in okra, Katung (1997) and Kuchinda (1998) reported on application metolachlor at 1.0 and1.5 kg a.i/ha and at 1.5 kg a.i/ha, respectively gave effective weed control in kenaf.

The taller plants height obtained from pendimethalin, butachlor and metolachlor in the years of study at both locations could be attributed to inter-specific competition for light by the roselle plants and weed as evidenced from herbicide treatments producing taller plants (Adekpe and Adigun 2000; Adigun, 2009; Mohammed *et al.* 2012). A similar result was also reported by Singh and Singh (1994). The more number of primary, secondary and tertiary branches obtained dueto pre-emergence application of pendimethalin, metolachlor and butachlor might be asa result of their weed control effectiveness at the critical period of weed competition, which promoted leaf expansion and smothering of the underlying weeds below the crop canopy. These results are in conformity with the findings of Ajakumar and Thakra (1993) who reported more number of secondary and tertiary branches in chilli pepper (*Capsicum annum* L.) as a result of lower number of plant population. Improvement in the number of leaves and thicker stem in the trials could also be attributed to more availability of plant growth resources, which in turn caused weed suppression by smothering. The weed control treatments did not have significant effect on number of days to 50% flowering and on days physiological crop maturity of roselle, these characters might be strongly controlled genetically.

The application of pendimethalin, butachlor and metolachlor each at available rates suppressed weeds and produced higher growth characters only up to period of 6WAS, with the exception of treatments with diuron and oxadiazon. This might be as a result of diuron ability to provide season long effective weed control, due to its persistence in the soil and the fact that it is more effective on broad-leaves weeds than grasses (Akobundu, 1987). Oxadiazon has low solubility in water and it is strongly adsorbed to soil colloids and resists leaching. Though the two herbicides, diuron and oxadiazon were much effective on weeds than pendimethalin, butachlor and metolachlor, but the later were more tolerated by roselle

The greater growth performances of roselle under hoe-weeding at 3, 6 and 9WAS compared to other weed control treatments and the unweeded plots could be explained in the light of improvement of soil physical properties by pulverizing the soil.that accompanied the physical method of weed control. Lio (2006) reported that physical method of weed control resulted in increased nutrients use efficiency, aeration and water infiltration and good aeration enhances absorption of most nutrients.In addition, mechanical/manual weeding opens the soil surface and enhances water penetration (Das, 2011).

The weedy check significantly suppressed crop growth characters such as plant height, number of leaves, stem girth, numbers of primary, secondary and tertiary branches compared with the best treatment obtained.This could be as a result of unchecked weed compete for growth resources, which resulted in lower crop vigour and shorter plants. It might also be due to intra-plant competition which lasted for longer period and hindered the plants from growing taller.

5.2.3 Effects of weed control methods on yield and yields components of roselle

The roselle yield components such as number of calyx/plant, calyx weight/plant and calyx yield/ha were significantly enhanced by two and three hoe-weedings and herbicide treatments compared to weedy check.Thus herbicide treatments and two and three hoe-weedings effectively controlled weeds in roselle, which in turn reduced inter-specific competition for growth factors with the weeds, thus permitting a better crop growth and development. This result is in line with the findings of Adekpe and Adigun (2000), Adigun (2009) on application of pendimethalin and metolachlor on roselle.

However, calyx yields obtained in roselle crop treated with pendimethalin, metolachlor, butachlor, and oxadiazon each at 1.5 and 2.0 kg a.i /ha respectively and diuron at 2.0 and 2.5 kg a.i /ha in 2012 were higher than the yield obtained from weedy check at both locations. This could be attributed to the tolerance of aforementioned herbicides and non-phytotoxicity exhibited on the crop at the applied rates. In effect, the herbicides exhibited broad spectrum control of grasses, broad-leaves weeds and sedges, which were common at the two experimental sites in the years of study as shown in Tables 3 and 4. The result obtained is in conformity with the findings of Adekpe and Adigun (2000) on pendimethalin at 1.0 and1.5 kg a.i /ha and metobromuron plus metolachlor at 2.0 kg a. i/ha which gave higher fruit yield of roselle than the weedy check. Adigun (2009) further reported higher fruit weight of roselle than control as a result of metolachlor plus metobromuron at 1.0+1.0 kg a.i /ha.Similar trends were also obtained in 2011 at both locations, except with diuron at 2.0 and 2.5 kg a.i/ha and oxadiazon at 1.5 and 2.0 kg a.i/ha, which gave in significantly lower calyx yield. This could be as a result of phytotoxicity of both herbicide at the applied rates in that season at both location, coupled with the percentage partlicle size distribution of soil as showed in Tables 1 and 2 and rainfall that fell some hours after application.The result obtained corrobate with the findings of Das (2011), who reported that application of diuron should be avoided on sandy soil and that heavy rainfall after application may affect cotton germination.

Of all herbicides treatments, metolachlor at 1.5 kg a.i /ha and pendimethalin at 1.5 and 2.0 kg a.i /ha produced consistently higher calyx yield throughout the years of trials at both locations compared to other herbicides possibly due to the tolerance of the two herbicides on roselle at the applied rates and its ability to control weeds effectively at critical periods of crop growth, which led to better higher calyx yield. Similar observations were also reported by Clewis *et al.* (2008), who observed heavier lint yield with application of metolachlor in cotton. Tunio *et al*. (2003) reported higher yield of cotton as a result of metolachlor and pendimethalin. Haruna *et al*. (2012) observed higher yield of okra as a result of metolachlor and pendimethalin at 1.0 kg a.i /ha. Khan *et al*. (2001) also reported increase in number of bolls/plant in cotton by pendimethalin.

The lower yield obtained from the weedy check could be attributed to weed competition suffered by the roselle plants during critical period of weed competition.The result obtained is in conformity with the findings of Adekpe and Adigun (2000) and Adigun (2009) who reported least calyx yield of roselle from weedy check. Lagoke *et al.* (1982), Katung (1997) and Kuchinda (1998) reported similar results on kenaf.

One hoe-weeding at 4WAS gave higher calyx yield than the weedy check but was not comparable with 2 and 3 hoe-weedings. Hoe-weeding once at 4WAS was obviously not adequate for effective weed control on roselle, as it was not comparable to two and three hoe-weeding in reducing weed infestation and does not provide a season long weed reduction in most crops, thus could not promote high calyx yield. Weed interference in crops is known to reduce crop yield components (Akobundu, 1987). Similar observations have been reported by Lagoke *et al*. (1981b), Kuchinda *et al*. (1991) on fibre and capsule yield reduction in kenaf and Adejonwo (1988) on fruit yield reduction in okro. The weed control treatment did not have significant effect on number seed/capsule, weight of seed/capsule and 100-seed weight. Thus, these attributes of yield are more under genetic control than the crop environment.

Generally, three hoe-weedings at 3, 6 and 9WAS in both seasons and combined means gave highest and more consistent yield performance, than the herbicide treatments. This is probably because the promising herbicide treatments including such as pendimethalin, metolachlor and butachlor at the rates applied did not persist long enough in the soil to take care of later emerged weeds like *Crotalaria juncea, Ageratum conyzoides, Rottboelia cochinchinensis, Cyperus rotundus and Cyperus iria*. Apart from this, diuron which had season-long effective weed control exihibited phytotoxic effect on roselle plants, though depending on environmental factors, while oxadiazon resulted in reduction on stand count and consequently depression of calyx yield which was not ameliorated by control of weeds by the said herbicide compared to hoe weeding at 3, 6 and 9WAS.

The combined analysis on yield at both locations showed that pendimethalin, metolachlor and butachlor each at 1.5and 2.0 kg a.i/ha gave significantly higher yield of calyx comparable to two hoe-weeding at 3 and 6WAS, but lower by diuron at 2.0 and 2.5kg a.i/ha, oxadiazon at 1.5 and 2.0 kg a.i /ha, hoe-weeding at 4WAS and weedy check. Similar observations were also reported by Adekpe and Adigun (2000) who reported higher fruit calyx yield in roselle as a result of application of pendimethalin at 1.0 and 1.5 kg a.i /ha. Haruna *et al.* (2012) reported higher yield of okra as a result of application of metolachlor and pendimethalin, each at 1.0 kg a.i /ha. Clewis *et al*. (2008) reported higher cotton lint yield with application of metolachlor. Mahar *et al*. (2007) who reported that pendimethalin as Stomp 330EC at 5L/ha gave higher productive cotton bolls similar with hand weeding. The highest yield obtained by three hoe-weedings at 3, 6 and 9WAS, showed that apart from controlling the weeds, weeding operation possibly loosened the soil which improved its aeration.

The weedy check significantly depressed calyx yield and the percent yield losses encountered due to uncontrolled weed inter-growth in the years of study at both locations were 72.68% and 24.54% at Samaru and 59.27% and 45.98% at Afaka in 2011 and 2012, respectively. The combined yield loss was 48.17 and 51.76% at Samaru and Afaka, respectively compared to the appropriate maximum obtained with the best treatments.

5. 3 Effect of Period of Weed Interference

5.3.1 Effects of period of weed interference on weed parameters.

Weed parameters such as weed cover score, weed dry weight and weed control index were significantly influenced by increase in the duration of period of weed interference. This indicated that as weeding was delayed, more weeds germinated and increased the level of infestation. In the years of study at both locations, plots initially left weed infested for 3WAS only did not have any serious effects on weed parameters.The weeds could not compete effectively with roselle plants to cause any remarkable adverse effects on growth and yield of the crop. This is because at this initial stage of crop establishment, the weeds and the roselle plants were too young and the soil nutrients, soil moisture and incoming solar radiation were still adequate to meet their combined requirements. During this period, weed cover score and weed dry weight were still low, but weed control index was high. Similar findings were reported by Adejonwo (1988) working on okra and Kuchinda (1998) on kenaf.Weed infestation throughout the crop life-cycle depressed the growth and yield of roselle in all the experiments. This result in calyx yield reduction by 60.76%, 59.4% and 61.11%, 48.12% while combined yield losses were 60.01% and 54.62% in 2011, 2012 at Samaru and Afaka, respectively compared to the maximum yield obtained when plots were kept weed free throughout the crop life cycle.

5. 3.2 Effect of period of weed interference on growth of roselle

Roselle growth characters were significantly suppressed in the years of study at both locations due to initial weed infestation from 6WAS and beyond and by keeping the crop weed free for 3WAS only. On the other hand, the growth characters such as plant height, number of leaves, stems girth, number of primary, secondary and tertiary branches were enhanced by keeping the crop weed free for 6WAS and beyond. This showed that initial weed infestation for 3WAS only and subsequent freedom from weed competition for 6WAS did not show significant negative effect on crop growth. But when the crop was subjected to initial weed competition for 6WAS and beyond, the detrimental effect of weed competition became prominent. The result is in conformity with the reports by Katung (1997) and Kuchinda (1998), who reported the same trend on kenaf and El-Naim *et al.* (2010) on roselle.

The plots initially left weed infested for 3WAS only did not have any serious effects on crop growth characters. In contract, growth characters in plots initially kept weed-free for 3WAS only were significantly depressed by subsequent weed infestation for the remaining part of the growth cycle.The young and tender grasses and few broad-leaves and sedges could not compete effectively with roselle at the early stage of 3WAS to cause significant effect on growth of the crops. This was probably because weed challenge commence mainly at 3WAS in most crops. Effective land preparation proceeded crop planted resulted in less weed competition by the crops. At the initial stages of crop growth, both the weeds and the roselle plants were too young and the soil nutrients and moisture contents as well as the solar radiation were still adequate to meet their combined requirements as pointed out by Kuchinda (1998). Hence, the effect of competition between weed and the roselle was not serious enough to affect crop growth. Similar findings were reported by Adejonwo (1988) and Kuchinda (1998) on okra and kenaf, respectively.

However, plots initially left weed infested for 6WAS and beyond depressed growth characters compared with crop kept weed free for 6WAS and beyond. This is because critical period of weed interference for most vegetable occurred between 3 and 6WAS and also at this stage, the parental endosperm food reserve might have exhausted and crop plants can no longer depend on it. So the competition at this stage is most serious since both crop plant and weed are actively growing and both striving to establish themselves at detriment of one another under limited supply of growth resources (Das, 2011).Similar findings were also made by Lagoke *et al*. (1981b) on kenaf, Dadari (1983) on cotton, Adejonwo (1988) on okra, Adigun *et al*. (1991) on pepper and Amador-Ramirez (2002) on chilli pepper. The result is also in conformity with the reports by Katung (1997) and Kuchinda (1998), who reported the same trend on kenaf and El-Naim *et al.* (2010) on roselle.

In order to obtain growth characters that were comparable to the weed free -check a weed free of 6WAS and beyond was required**.** Once the crop is kept weed free up to this period subsequent infestation did not have significant effect on its growth characters. Keeping the plots weed-free for 3WAS only was not enough to prevent its growth suppression by weeds because at this stage the crop had not formed the canopy required to suppress subsequent weed growth. Thus, there was full strength regeneration of weeds which competed adversely with roselle plant and consequently depressed the growth characters.

The most vigorous and tall plants with higher number of primary, secondary and tertiary branches, more number of leaves and thicker stem obtained on plots kept weed free throughout the growing periods which were comparable to those plots left initially weed infested for 3WAS only and those kept weed free for 6- 12WAS in the two years of study and locations may be attributed to reduced weed competition for growth characters during the critical (most detrimental) period of crop-weed competition, because weeding facilitates crop plants to have more resources. The result is in conformity with the findings of El-Naim and Ahmed (2010) and El-Naim *et al*. (2010), who observed similar trend on roselle.The least vigorous plant and shorter plants with less number of primary branches were obtained in the weedy check. This could be attributed to weed competition, which reduced the growth resources available for the crop growth, thereby reducing the capacity of the crop to develop these characters as reported by El-Naim and Ahmed (2010).

5.3.3 Effect of weed interference period on yield and yields components of roselle.

In the present study, maximum number of calyx/plant, calyx yield/plant and calyx yield/ha were obtained from plots kept initially weed free for 6WAS and longer and those initially infested for 3WAS only in 2011 and 2012 at Samaru and Afaka and the combined data at both locations, except in 2011 at Afaka, where calyx yield by plots kept weed free for 6WAS and longer and those that were infested for 3WAS only gave lower calyx weight per plant than the highest in the field, probably due to invasion by *Cuscuta compestris*.

These characters for these treatments were indeed higher than by the plots initially left weed-infested for 6WAS and longer, and those initially kept weed-free for 3WAS only.

Keeping the plots weed-free for 3WAS only was not enough to forestall growth suppression by weeds because at this stage the crop had not formed the canopy required to suppress subsequent weed growth. Thus, there was force rejuvenation of weeds which competed adversely with roselle plant and consequently depressed the yield components. Weeding of roselle fields need to begin as early as 3WAS in order to avoid calyx yield losses as a result of weed interference. The highest calyx yield was obtained when the crop was left initially weed infested for 3WAS only and subsequently kept weed-free until harvest and this was comparable to the yield obtained by keeping the crop weed-free for 6WAS and longer.

In the same vein, the plots that were left initially weed infested for 3WAS only and plots kept weed free for 6WAS and longer, resulted in significantly higher calyx yield than the other treatments. This could be due to the fact that initial weed infestation for 3WAS only and subsequent infestation after freedom from weed competition for 6WAS did not have significant detrimental effect on crop growth and development. The result is in conformity with the reports by Katung (1997) and Kuchinda (1998), who reported the same trend on kenaf and El-Naim *et al*. (2010) on roselle. Osundare (2009) on okra reported that early weed control could suppress the growth of weeds and thus create avenue for the survival of the plants. The result is also in conformity with Adigun (2003), who reported the same trend in roselle and Small (2006) and Osundare (2009) on okra. El-Naim and Ahmed (2010) reported that the highest calyx yield was obtained with frequent weeding in roselle. Similar observations were made by Ibeawuchi *et al*. (2005) who reported that component of yield and pod number per plant was severely reduced by weed competition in okra. The similar and greater calyx yield obtained from plots kept weed-free for 6WAS and longer and that left infested for 3WAS only might be attributed to the effect of timely weeding of the plots by the former which fell within the critical period of weed competition, and so the detrimental impact of weeds at this critical period was avoided. The latter fell at the initial stage of crop establishment in which both the weed and roselle plants were small and growth resources were still adequate to meet their combined requirements. This is in conformity with the findings by Saidu *et al*. (2012), who reported similar trend in okra. Calyx yield was generally not significantly improved with subsequent weeding beyond 9WAS; further weeding beyond this period seemed to cause depression in calyx yield in some cases.The yield depression by weeding beyond 9WAS may be attributed to possible damage to roots as a result of frequent hoe-weeding, particularly at the advance stage of crop growth when there was full canopy formation. Olunuga and Akobundu (1980) have similarly observed that the traditional hoe weeding is not only strenuous, labour-intensive and time-consuming, but may also cause damage to the crop roots and stems with subsequent yield losses.

The calyx yield reductions as a result of weed infestation throughout the crop life-cycle in 2011 and 2012 were 60.76% and 59.40%, and 61.11% and 48.12% at Samaru and Afaka, respectively. The non-significant effects of period of weed interference on numbers of seeds/capsule, weight of seed/capsule and 100 seed weight can further suggest that these charactersare genetically controlled in the crop (Katung, 1997).

5.4 Critical Period of Weed Competition on Roselle.

The result obtained from Fgures 1-6 indicate that the critical period of weed competition in roselle was between 4 and 6WAS. The figure shows that the periods are divided into three.

Period I:-This is between period 0-3WAS. At this stage the calyx yield loss due to presence of weeds was minimal but increased as the time curve goes beyond this period.

Period II:- This is from 3-6 WAS, when there was sharp decline in yield as weed infestation period increased and on the other hand sharp increase in yield as the weed free period increased. This is the critical period of weed competition in roselle and the crop must be kept weed free to avoid significant yield loss.

Period III: - This is from 6-12 WAS.This period is not that critical for crop growth and weed infestation does not cause significant yield reduction. Weeds present during this period cause physical interference with harvesting, contaminate harvested produce and build up weed seed population in the soil.

The results from the trials showed that weeds are not equally damaging all through the growing period of a crop, but at period II, weeds are more harmful to crop growth and yield. Allowing weeds to grow with crop for initial 3WAS only, and then removing them for the rest of the crop life cycle enhanced calyx yield; whereas keeping the crop weed free for the same period and allowing subsequently weed infestation is bad as allowing weed infestation throughout the crop life cycle. Weed infestation in the weedy check and weed free in the weed free control recorded the lowest and highest calyx yield, respectively. However, instances occurred at Samaru in 2011 and 2012 at Afaka, when weed free period for 9WAS had the highest calyx yield. This could be as a result of losses of stand count due to frequent weeding operation which in turn affected the yield as indicated by Zimdahl (1980) and Akobundu (1987). The higher calyx yield was obtained when plots were kept weed free for 6WAS with 99.18 and 100% in 2011 and 98.92 and 96.10% in 2012 at Samaru and Afaka, respectively. This shows that weed growth after the critical period (beyond 6WAS) certainly could reduce crop yield, but not to a significant level (Zimdahl, 1980). Lagoke *et al*. (1982) have estimated the critical period of weed competition for kenaf to be between 3 and 4 WAS, Douti (1997) reported 4 and 7WAS on cotton while Katung (1997) and Kuchinda (1998) confirmed it to be between 3 and 6WAS on kenaf. This period which falls in period II of the curve (drastic reduction or increase in yield) revealed that at this period, the crop must be kept free from weeds infestation in order to avoid significant yield loss. This period also coincides with the time of maximum weed dry matter production and competition with roselle plants. Leaving the weeds unchecked for up to 6WAS and beyond will have adverse and irreversible effect on crop yield despite subsequent removal of the weeds.

In another development, weed infestation for 6WAS significantly reduced calyx yield by 43.80% to 61.10 % and 30.90% to 58.88% in 2011 and 2012 at Samaru and 50.00% to 56.25% and 40.04% to 43.33% in 2011 and 2012 at Afaka, respectively. This can be compared to yield losses of 2.14% and 2.83% in 2011 and 2012 at Samaru and 0 and 0.64% in 2011 and 2012 at Afaka, respectively, when the crop was kept weed free throughout its life cycle. Similarly, unchecked weed growth for 6WAS resulted in calyx yield losses of 12.55% and 14.56% in 2011 and 2012 at Samaru and 11.11% and 6.72% in 2011 and 2012 at Afaka, compared to yield losses of 0.81 and 1.08% at Samaru and 0 and 3.9% at Afaka in 2011 and 2012, respectively, when the crop was kept weed free for the corresponding period.

However, the crop initially kept weed free for 3WAS only resulted in yield reductions of 61.41% and 63.01% at Samaru and 55.55% and 48.36% at Afaka in 2011 and 2012, respectively, compared to weed infestation for the corresponding period. The unchecked weed growth throughout the crop life-cycle caused 60.76%, 59.40% and 61.11% and 48.12% in 2011, 2012 at Samaru and Afaka, respectively while combined data yield losses were 60.01% and 54.62% at Samaru and Afaka, respectively, compared to the maximum yield obtained when plots were kept weed free throughout the crop life cycle.

5.5 Correlation Analysis

The strong and positive association between yield and the various growth and yield characters tested in this study indicate the impact of vegetative growth and yield development on yield as well as the interdependency of the characters. There were positive and significant correlations between calyx yield and plant height, number of leaves, stem girth, number of primary and secondary branches at 9WAS, number of calyx and calyx weight/plant in the weed control experiment as well as in weed interference period experiment in both years and locations. Similar results were obtained by Lagoke *et al.* (1981) on okra, Kumar *et al*, (1985) on roselle Katung (1997) and Kuchinda (1998) on kenaf and Idris *et al.* (2007) also on kenaf.

This suggests that these characters are most critical determinants of calyx yield in roselle and thus, should constitute primary altributes to be considered by breeders for the roselle crop improvement.They represent the criteria useable by plant breeders in selecting high calyx yield in roselle in breeding programs.The moderate and highly significant positive association between calyx yield and stem girth indicated yield dependency on this growth character. Such consistent correlations in the two seasons and locations were indicative of considerable importance of the characters as calyx yield contributing factors in roselle. Similar associations between yield and growth characters were reported by Adejonwo (1988) and Sunday and Ariyo (2008) on okra. Al-Barrack (2006) also reported that fruit yield of Canda (*Brassica napus .L.*) is a function of yield component. The highly significant and positive correlation between number of leaves and calyx yield may be attributed to larger leaf area, which enhanced photosynthesis and associated dry matter accumulation in the calyx.

The strong relationship between calyx yield and plant height showed that plant height directly determines the amount of photosynthate available for growth, and development of calyx yield. Similar result was obtained by White *et al.* (1970) on kenaf. The negative and highly significant correlation between calyx yield and weed dry matter demonstrated the deleterious effect of weed competition, which eventually resulted in yield depression. It could also be said that rapid weed growth and dry matter production impact adverse competition on crop plants for the various growth factors, and this in turn impairs crop growth and development of calyx yield. Katung (1997) and Kuchinda (1998) made similar assertion in weed competition studies in kenaf at Samaru. Adigun (1984), Bakut (1985) and Bulus (1985) have all reported that yields of crops were negatively correlated with weed dry weight.

5.6 Profitability

The effectiveness of crop production system is ultimately evaluated on its profitability. The acceptance of new technology by the farmers depends on the economics of production of the crop using the technology. Among the different indicators of monetary efficiency in any production system, the economics in terms of net-returns has a greater impact on the practical utility and/or acceptance of the technology. Therefore, economic analysis is the basic tool in determining which treatments gives the highest net-farm income or net return per naira invested.

In the present study, the data obtained revealed that there was an overall increase in net income by weed control treatments compared to the weedy check (untreated control). The net farm income on calyx yield was optimum under three hoe-weeding at 3, 6 and 9 WAS, although there were insignificant differences between this treatment and pendimethalin at 1.5 kg a.i/ha or metolachlor at 1.5 kg a.i/ha in both seasons and locations.This indicates that with appropriate herbicide rate for weed control can be a profitable venture. This is to say that herbicide use provides convenient, economical and effective way in managing weeds and save time for farmers to perform other tasks (PSCAS, 2017).

In 2011 and 2012 at Samaru, net-farm income obtained by hoe-weeding at 3, 6 and 9 WAS were ₦96,450.00 and ₦116,150,00 compared to ₦100,000.00 and N114,000.00 by pendimethalin at 1.5 kg a.i/ha in the respective seasons. In 2011 and 2012 at Afaka hoe-weeding at 3, 6 and 9WAS gave net-farm income of ₦27, 250.00 and ₦53, 450.00 while pendimethalin at 1.5 kg a.i/ha and metolachlor at 1.5 kg a.i/ha gave₦24, 000.00 and ₦53,750.00 net-farm income, respectively. The higher net-farm incomewere obtained at both locations and years of study from pendimethalin at 1.5 kg a.i/ha in 2011 at Samaru and metolachlor at 1.5 kg a.i /ha in 2012 at Afaka while in 2011 and 2012,hoe-weeding at 3,6 and 9WAS also gave higher net-income at Afaka and at Samaru, respectively. The hoe-weedings proved the most expensive weed control method for the production of roselle as it resulted in the highest total cost of production (₦59,150), followed by hoe-weeding at 3 and 6WAS (₦56,150)compared to total cost of production on two herbicides treatments ₦55,100 and ₦54,050 of pendimethalin and metolachlor, respectively. These values could not justify its profitability, especially the drudgery associated with weeding and non-availability of labour, which could be avoided when herbicides are used at the recommended rate (Adigun *et al.* , 2003, Adeshina, 2009).

The higher net-farm income obtained from pendimethalin at 1.5 kg a.i/ha and metolachlor at 1.5kg a.i/ha in years of study at both locations could be a clear indication of the effectiveness and timeliness of the weed control method over other control measures. This could also be as a result of better weed control exhibited by the herbicide treatments, which were cheaper, faster and more adaptable to large scale crop production than manual hoe-weeding (Chikoye *et al*. 2005; Chikoye *et al*. 2007). The results obtained in these trials showed that use of herbicides was more profitable in roselle production than hoe-weeding due to its convenience, economy and effective way of weed management. This is similar to the findings of Warade *et al.* (1995), Siakia *et al.* (1997), Kehinde (2002) and Khan *et al*. (2005), who reported optimum returns with application of herbicide compared with other methods of weed control. Sinha and Lagoke (1984), Bakut (1985), Ogunbile and Lagoke (1986), Lagoke and Shebayan (1988), Adigun *et al*. (1993) and Adigun and Lagoke (2003) reported that herbicide use is more profitable than hoe-weeding in the production of various crops in Nigeria. The result obtained in this investigation is in line with the findings by Nazeer *et al*. (2004), who reported that a very lucrative cost-effective gain was recorded due to the application of buctril-M at 1.6 kg a.i/ha (Bromoxynil-group 6) on wheat and the gain in yield from hand weeded plot was nullified by additional cost of weeding. Also, lower net-farm incomes were obtained from application of diuron and a weedy check in 2011 and 2012 at both locations.This lower net-farm incomes obtained from diuron, especially in 2011 at Afaka could be as a result of phytotoxity effect of the herbicide exihibited on roselle in that location at the given rates.

On the profitability of roselle production in experiment II, (period of weed interference), there was variation in total revenue of roselle between the years at the same location. This could be as a result of crop invasion by parasitic weed (*Cuscuta competris .L.*),which effect was more in 2011 at Afaka, and this reduced the total revenue of roselle obtained in the field. The analysis of profitability of roselle on period of weed interference revealed that total cost of producing roselle on the field that is kept weed free throughout the crop life-cycle was ₦69, 100 for each location, compared to ₦53, 100 for weed free for 3WAS, ₦56, 100 for weed free for 6WAS, ₦59,100 for weed free for 9WAS, and ₦62,100 for weed free for 12WAS respectively, which were close in values. This may be so because of the labour which was required to weed to achieve freedom from weeds for the respective periods. The revenue was higher in 2012 with ₦199, 700.00 compared to ₦181, 300.00in 2011 at Samaru and in2012 with₦155, 400.00 compared to ₦15, 000 in 2011 at Afaka. These could be as a result of higher roselle yield in 2012 than 2011 in both locations.

The net-farm income of roselle production were higher in both locations when the crop waskept for 6WAS with ₦123, 800.00 and ₦141, 500.00 at Samaru and –₦41,000.00 when the crop was kept for 6WAS and ₦96,300.00 when the crop was kept weed free for 9WAS at Afaka in 2011 and 2012, respectively showing the profitability of the enterprises on roselle production. However, the revenue was lowest when plots were kept weed free for 3WAS only at both locations. This was because, at this stage the weeds were still very young and it was a waste of time and money to weed the field which emerged and exert serious competition against the crop plants.The revenues were also low when weeds were left unchecked which were ₦71, 100.00 , ₦81,100.00 at Samaru and ₦5,800.00, ₦80,600 at Afaka in 2011 and 2012, respectively. The revenue by crop kept weed free for 3WAS only was slightly lower than by the weedy check because weeding was not carried out throughout the crop life cycle in the later.

However, it was observed that net-farm income for crop kept weed free for 6WASwas higher throughout the years of studies except in 2012 at Afaka. This may be as a result of the crops planted had escaped critical period of weeds interference when the weeds were controlled earlier, and continous weeding after 6WAS increased cost of production which may later reduced stand count at harvest and at the end decreased net income of the farmers.The comparable value of net-income by crop kept weed free for 6WAS and others weed free and interference period is an indication that the earlier the weeds controlled of weed emerged and the competition of the weed at later stages after critical period of weed interference do not pose serious harm on crop yield, and consequently income per naira invested.

So, it is therefore recommended to farmers to kept his plots free of weed for 6WAS and to note that to continue weeding till 9 to 12WAS would not give any yield and income advantage.

5.7 Proximate Analysis

5.7.1 The calyx

The calyx which is the most exploited produce of roselle plant (Schippers, 2000) is obtained by separating the calyxes from the remains of flower and capsules containing the seeds.The chemistry of the dried calyx obtained revealed that the herbicides used did not influence the nutritional and essential mineral composition present in the calyx which implied that the herbicides used its safer for human consumption, since the application of the herbicides evaluated did not affect the nutritional contents of the calyx.The result obtained revealed that calyx extract contains healthy nutrients and concentration of essential mineral ion that are useful for maintaining healthy and prevention of chronic and degenerative diseases.The results obtained are in line with the findings of Braithwaite

(1981), who reported that no change was observed in okra quality, total carbohydrate, protein and fat contents as a result of herbicides application. Dobrzanski (1978) also reported that herbicides had no effect on total sugar in onions and vitamin C in Brussels sprouts.Many researchers have reported the importance of the mineral, nutritional constituents and mineral composition found on calyx in human's development, Rao, (1996); Yagoub *et al*., (2008); Nzikou *et al*., (2011) and Shaheen *et al*., (2012). The high value of ascorbic acid present in calyx of roselle shows it helps in healing and maintaining bones and teeth.The presence of protein in calyx makes it suitable for building and repairing worn-out body tissue. Ash helps in measuring the total amount of mineral present within the calyx**.**Vitamin B helps the body to convert food (Carbohydrate) into fuel (Glucose) which is used to produce energy. The B-complex vitamin is needed for healthy skin, hair, eyes and liver.The Vitamin D helps in regulating the immune system and neuromuscular system. Fibre in calyx helps in improving intestinal digestion by reducing the number of goblet cells present in the intestine and hence reduces the amount of goblet mucin which acts as a luminal barrier against absorption.

In another development, Iron is an essential mineral, whose major function in combination with protein and copper, helps in manufacture of haemoglobin which transports blood through the body. Myoglobin found in the muscle tissue also contains Iron which assists in the transfer of oxygen into the muscles. Iron is important for protein metabolism and immune system. The presence of Calcium in the calyx helps in maintaining the p^H of the blood and regulating cell membrane. It helps in the prevention of insomnia and irregular heartbeat. It is also essential for the prevention of high blood pressure and in maintaining balance (homeostasis) in the body. The juice from the calyx extract contains high amount of anthocyanin which protects the body from several diseases attributed to the reactions of free radicals (Killima *et al*., 2014). Therefore, consumption of roselle calyx juice, which contains anthocyanin, will protect the human body from several diseases attributed to the reactions of free radicals.

CHAPTER SIX

6.1 SUMMARY AND CONCLUSION

Two field trials were conducted during the wet seasons of 2011 and 2012 at the experimental farms of the Institute for Agricultural Research, Samaru (Lat. 11^0 11^1, Long. 07^0, 38^1; 686m above sea level) and Federal College of Forestry Mechanization, Afaka (Lat 10^0, 03^1, Long. 07^0, 21^1; 644m above sea level), both in the northern Guinea savanna zone of Nigeria. The aim was to evaluate the influences of weed control methods and weed interference period on growth and yield of roselle.The first experiment consisted of fourteen weed control treatments (oxadiazon at 1.5 and 2.0kga.i/ha, diuron at 2.0 and 2.5 kg a.i /ha, metolachlor at 1.5 and 2.0kg a.i /ha, butachlor at 1.5 and 2.0 kg a.i /ha and pendimethalin at 1.5 and 2.0kg a.i /ha, hoe weeding (HW) at 4; HW at 3 and 6 and HWat 3,6 and 9 weeks after sowing (WAS) and a weedy check). The second experiment comprised of ten periods of weed interference designed in two sets: In the first set, plots were kept weed free initially by hoe-weeding for 3, 6, 9 and 12WAS and left weed infested thereafter; and in the second set, plots were left weed infested initially for the corresponding periods and kept weed free thereafter. There were two controls: plots kept weed free throughout the crop life-cycle and plots left weed infested throughout the crop life-cycle. Each experiment was laid out in randomized complete block design (RCBD) and replicated three times.

The weed parameters measured in Experiment I included: weed cover score, weed dry weight and weed control index at 3, 6, 9 and 12 WAS and herbicide efficiency index at 12WAS. Crop growth parameters taken included percentage seedling emergence score, at 2WAS, crop injury score at 2WAS, number of leaves, plant height, stem girth/plant, numbers of primary, at 3, 6, 9 and 12WAS, secondary and tertiary branches/plant at 6 9 and12WAS.The yield characters measured were number of calyx/plant, calyx weight/plant and calyx yield. The yield components included number of seeds/capsule, weight of seeds/capsule and 100 seed weight. In Experiment II: Similar readings were taken, except herbicide efficiency index at 12WAS, percentage seedling emergence score and crop injury score. In Experiment I, the herbicide treatments could not effectively control the weeds beyond 6WAS, except diuron at 2.0 and 2.5kg a.i /ha and oxadiazon at 1.5 and 2.0kg a.i /ha. Application of diuron at 2.5kg a.i /ha gave significantly lower weed cover, weed dry matter and higher weed control index than the other herbicide treatments and was comparable to two hoe-weeding at 3 and 6WAS at all sampling periods. Highest crop injury was by diuron at 2.5kg a.i /ha in 2011 at both locations. Among herbicides, pendimethalin, metolachlor and butachlor each at 1.5 and 2.0kg a.i /ha were consistent in combining good weed control with higher crop growth and yield attributes. Pendimethalin at 2.0kg a.i /ha gave significantly higher herbicide efficiency index in the years of trials and locations, more number of leaves, taller plant, thicker stem, more numbers of primary, secondary and tertiary branches compared to other herbicide treatments. In turn, more number of calyx/plant, higher calyx weight/plant and calyx yield were obtained, except in 2012 at Afaka where metolachlor at 1.5kg a.i /ha gave higher yield of calyx than the other treatments. More number of seeds/capsule, higher weight of seeds/capsule and greater 100 seed weight were also obtained from pendimethalin at 2.0kg a.i /ha than the other herbicide treatments. The treatment also gave higher mean calyx yield at both locations. In Experiment II at both locations and years, uncontrolled weed growth for 6WAS and longer significantly depressed the growth and yield characters of roselle compared to crop kept weed free for the corresponding periods. Keeping the plots weed free initially for 3WAS only did not prevent suppression in crop growth and yield, while initial weed infestation for 3WAS only had no adverse effect on roselle plants. Keeping the plots weed infested for 6WAS and longer reduced crop growth characters and calyx yield compared to the crop kept weed free for 6WAS and beyond. The crop was most critically affected by weed interference between 4 and 6 WAS. Plots kept weed free for 6WAS and beyond produced calyx yield comparable to those kept initially weed infested for 3WAS. Number of seeds/capsule, weight of seeds/capsule and 100 seed weight were not significantly affected by any of the factors evaluated in the two experiments and the two years of studies. In both experiments, uncontrolled weed growth throughout the crop life-cycle significantly depressed the growth and yield of roselle plant: Calyx yield were reduced by 72.68%, 24.54% and 59.27%, 45.98% in 2011, 2012 at Samaru and Afaka respectively. The combined yield losses at both locations were 48.17% and 51.76% at Samaru and Afaka, respectively in weed control experiment. In the weed interference experiment the yield losses as a result of weed infestation throughout the crop life-cycle were 60.76%, 59.40% and 61.11%, 48.12% in 2011, 2012 while combined yield losses were 60.01% and 54.62% at Samaru and Afaka, respectively. Simple correlation matrix in the two experiments revealed that plant height, number of leaves, stem girth and numbers of primary and seondary branches at 9WAS and number of calyx/plant and calyx yield/plant were positively and highly correlated with calyx yield. The cost benefit analysis for weed control at Samaru in 2011 and 2012 showed that pendimethalin at 1.5 kg a.i /ha gave the best economic returns of ₦100,000.00 and ₦114,000.00, while at Afaka, pendimethalin and metolachlor each at 1.5kg a.i /ha gave ₦24,800.00 and ₦53,750.00 in 2011and 2012, respectively. Hoe- weeding at 3, 6 and 9WAS gave ₦96, 450.00 and ₦116, 150.00 and ₦ 27,250.00 and ₦ 53,350.00 in 2011 and 2012 at Samaru and Afaka, respectively.

In Experiment II , plots kept weed free for 6WAS gave best economic returns of ₦123,800.00 and ₦141,500.00 in 2011 and 2012 at Samaru and plots kept weed free for 6WAS and 9WAS gave –₦41,100.00 and ₦96,300.00 in 2011 and 2012 at Afaka respectively when compared with plots kept weed free throughout the crop life-cycle with ₦108,400.00 and ₦125.000.00 at Samaru and – ₦54, 100,and ₦85,300.00 at Afaka in the respective years of studies. The nutritional and mineral composition of calyx on basis of weed control methodsshowed that protein, fibre, ash, iron, calcium, ascorbic acid and vitamins B1, B2, D and B complex contents had similar values, irrespective of treatment.

Based on the findings obtained in the present investigation, it can be concluded that:

Weed control

- For effective weed control and higher yield of calyx, best herbicide alternatives to conventional hoe-weeding at 3 and 6WAS is application of pendimethalin at 1.5 kg a.i/ha or metolachlor at 1.5kg a.i /ha.
- In the combined data the percentage yield gains by best alternatives were 25% and 7.9% at Samaru and 47% and 4.1% at Afaka compared to conventional hoe- weeding at (3 and 6WAS).
- The best herbicide treatment (pendimethalin at 1.5 kg a.i /ha) gave best income of best returns of ₦100.000.00 and ₦114,000.00 compared to two hoe-weeding that gave ₦87,550 and ₦99,150.00 in 2011 and 2012 at Samaru. At Afaka best herbicide treatments were (pendimethalin and metolachlor) each at 1.5kg a.i/ha gave best returns of ₦24,800.00 and ₦53,750.00 compared to two-hoe-weeding that gave ₦27,250.00 and ₦ 53,350.00, in 2011 and 2012 during the years of studies.

- The combined yield losses at both locations were 48.17% and 51.76% at Samaru and Afaka respectively as a result of (no weeding) weed infestation throughout the crop life-cycle.

Weed Interference:

Based on the findings obtained in the present investigation, it can be concluded that:

- In both locations, farmers should keep roselle crop weed free between 4 and 6 weeks after sowing in order to obtain maximize calyx yield.
- The critical period of weed interference was between 4 and 6 WAS.
- To maximize the profit for every naira invested, the farmers should keep the crop weed free for 6WAS at Samaru and 6-9WAS at Afaka.
- Themaximum weed infestation period, plots could be left weed infested for 3WAS only in order to obtain maximum yield comparable to the weed free check.
- The combined calyx yield losses as a result of untreated (weedy check) were 60.01% and 54.62% at Samaru andAfaka, respectively.

6.2 Recommendation

- Roselle farmers can use pendimethalin at 1.5 kg a.i /ha or metolachlor at 1.5kg a.i /ha to control weeds in roselle.
- It is suggested that further work should be carried out on diuron and oxadiazon to include lower rates due to fluctuating results in the two years and locations with the available rates in the current study.
- Also, screening of large population of roselle varieties for differential response of oxadiazon and diuron with the available rates used in the trial.
- Farmers should keep roselle weed free from 4-6WAS for maximum calyx yield.

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Appendix I: Samaru Meteorological Observation during wet season of 2011.

	Rainfall	Temperature (^{0}C)		Relative humidity	Sunshine
Month	(mm)	(max)	(min)	(%)	hours
June	162.5	32.3	20.9	76.5	6.2
July	223.9	30.8	20.0	58.4	6.1
August	239.9	30.2	18.9	80.2	4.7
September	113.8	32.3	18.9	76.2	4.4
October	54.0	34.1	18.2	64.9	6.6
November	0.00	34.2	18.6	18.0	8.9
Total	794.1				

Source: Meteorological Station, Institute for Agricultural Research, Samaru-Zaria.

Appendix II: Samaru Meteorological Observation during wet season of 2012.

	Rainfall	Temperature (^{0}C)		Relative humidity	Sunshine
Month	(mm)	(max)	(min)	(%)	hours
June	120.7	32.0	12.9	76.1	6.7
July	165.3	30.1	20.3	82.6	5.3
August	426.7	29.1	19.5	82.3	4.5
September	270.3	30.4	19.8	77.2	5.0
October	79.6	33.8	20.8	70.2	7.3
November	0.00	34.3	17.4	32.9	8.6
December	0.00	31.4	12.5	16.9	7.6
Total	1062.6				

Source: Meteorological Station, Institute for Agricultural Research, Samaru-Zaria.

Appendix III: Afaka Meteorological Observation during wet season of 2011.

Month	Rainfall (mm)	Temperature (^{0}C) (max)	(min)	Relative humidity (%)	Sunshine hours
June	80.9	30.8	21.3	76.0	5.4
July	240.3	29.3	20.5	78.0	5.12
August	208.0	28.6	20.7	82.0	4.9
September	118.7	30.3	20.4	80.0	6.1
October	72.7	31.5	20.0	73.0	5.9
November	0.00	33.0	14.6	37.0	9.4
December	0.00	31.1	14.2	36.0	9.2
Total	720.6				

Source: Meteorological Unit, Forestry Research Institute of Nigeria, Federal College of Forestry Mechanization, Afaka Kaduna, Nigeria.

Appendix IV: Afaka Meteorological Observation during wet season of 2012.

Month	Rainfall (mm)	Temperature (^0C) (max)	(min)	Relative humidity (%)	Sunshine hours
June	100.3	30.1	20.8	76.0	4.7
July	225.6	28.5	20.4	78.0	4.5
August	346.2	27.7	20.3	83.0	4.0
September	203.3	29.3	20.4	80.0	5.4
October	135.1	31.8	21.0	75.0	7.3
November	0.00	33.7	17.0	46.0	8.5
December	0.00	32.1	15.5	30.0	9.1
Total	1010				

Source: Meteorological Unit, Forestry Research Institute of Nigeria, Federal College of Forestry Mechanization, Afaka Kaduna, Nigeria.

AppendixV: Qualitative description of treatments effect on weeds in the visual cropping scale of 1-9.

Effect	Rating	Weed Control Description
Slight	1	Good to excellent control
	2	Good control
	3	Satisfactory control
Moderate	4	Moderate control
	5	Deficient control to control
	6	Deficient control
	7	Poor to deficient control
	8	Poor control
	9	Very poor control

Appendix VI: Qualitative description of treatments effect on crop vigor score in the visual cropping scale of 1-9

Effect	Rating	Weed control description
Slight	1	Moribund (few green leaves observed)
	2	Only few green tissues presents
	3	Definite growth reduction, severe toxicity symptoms and less likely to survive.
Moderate	4	Apparently making some growth
	5	Distinguishable inhibition of growth and other injury symptoms.
	6	Distinguishable inhibition of growth and slightly discoloration and other injury symptoms.
	7	Distinguishable inhibition of growth.
	8	Slightly discoloration and low vigor, discoloration and necrotic spots.
	9	Slightly discoloration and lower vigor.

BIOGRAPHY

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- Teaching Kaduna State Ministry of Education Govt. Girls Secondary School, M/Gwarzo (NYSC)	1997-1998
- Abubakar Gumi College, Kaduna	1998-1999
- Ahmed Farm Nig. Ltd. Kaduna	1999-2005
- Federal College of Forestry Mechanization, Afaka Kaduna	2010-Date