

**THE INFLUENCE OF SPACING AND PLANT AGE AT FIRST  
HARVEST ON THE GROWTH, DEVELOPMENT, AND YIELD OF  
THREE ROSELLE (*Hibiscus sabdariffa* L.) CULTIVARS**

**BY**

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## DECLARATION

This study is the outcome of research undertaken by Sualey Abukari, apart from the references to the works of other researchers which have been duly cited towards the award of Master of Philosophy Degree in Crop Science in the Department of Crop Science, University of Ghana, Legon.

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## ABSTRACT

A field experiment was conducted to examine optimum plant population and compare yields of three local roselle cultivars; namely Bihi, Mogla 1 and Mogla 2 planted at four different spacings and harvesting at 31 days after planting by pruning the plant at 13.0 cm high. Subsequent harvesting of shoots was done at fortnightly intervals. The spacings were; 30cm x 30cm, 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm. A pot experiment was also carried out to determine the appropriate plant age at first harvest (PAFH) of two of the roselle cultivars; Bihi and Mogla 1. Three PAFH used were 31, 38 and 45 days after planting. The field and pot experiments were conducted at the University of Ghana Farm, Legon from June 2012 to January 2013.

A randomized complete block design was used and replicated four times for the field experiment and three times for the pot experiment. In the field experiment, plant growth parameters studied were harvested leaves, stems and petioles numbers, fresh and dry weights were recorded at 31 days after planting and depending on the type of treatment of PAFH in the pot experiment. Other data collected were; plant height at first harvest, number of leaves per plant, number of new shoots per plant, new stem diameter, leaf area, leaf area index, yield and yield components. Results revealed that subsequent harvesting did not significantly enhance the production of more harvested leaves and stems in the field experiment; and reduced new shoots length in both field and pot experiments. The Bihi cultivar was taller at first harvest than Mogla 1 and Mogla 2 at closer spacing than wider spacing. PAFH of 45 days produced taller plants, more harvested leaves and stems than 31 and 38 days with insignificant differences between 38 days PAFH. The studies showed that optimum spacing was 30cm x 30cm (222,222 plants/ha). Mogla 1 produced higher fresh leaves, stems, shoot yields (t/ha), leaf/stem ratio than Bihi and Mogla 2. Appropriate plant age at first harvest of 38 days after sowing is recommended for continuous harvesting by pruning as a leafy vegetable to maximize production.

## DEDICATION

I dedicate this work to my late father, mother, and my beloved wife and children,  
Mariam, Toyibu and Toyiba.



## ACKNOWLEDGEMENTS

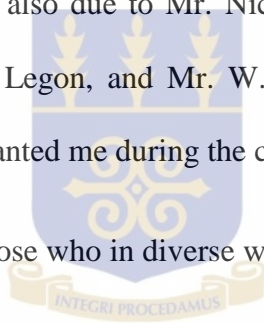
I am grateful to the Almighty Allah for giving me good health to be able to successfully accomplish this research work.

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## LIST OF ABBREVIATIONS

Bihi	=	Bihinayili
DAS	=	Days After Sowing
FLY	=	Fresh leaf yield (t/ha)
LAFH	=	Leaf area at first harvest
LAI	=	Leaf Area Index
LAI FH	=	Leaf Area index at first harvest
LAILH	=	Leaf index at last harvest
LALH	=	Leaf area at last harvest
MNSL	=	Mean new shoot length
Mogla 1	=	Moglaa 1
Mogla 2	=	Moglaa 2
PAFH	=	Plant age at first harvest
PHFH	=	Plant height at first harvest
THLNP	=	Total harvested leaf number/plant
TLDWP	=	Total leaf dry weight/plant
TLFWP	=	Total leaf fresh weight/plant
TLNP	=	Total leaf number/plant
TLVs	=	Traditional leafy vegetables
TSDWP	=	Total shoot dry weight/plant
TSFWP	=	Total shoot fresh weight/plant
TSNP	=	Total shoot number/plant
WAP	=	Weeks after planting

## CHAPTER ONE

### 1.0 INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is one of the most important traditional leafy (TLVs) vegetables in the tropics and sub-tropics. It belongs to the malvaceae family. It is believed to have originated from Africa (Grubben, 1977 ; Murdock,1995; Grubben and Denton ,2004). Several names have been attributed to roselle such as Sour-Sour, Indian, Jamaican or Red Sorrel, Bissap, and Karkade (Tindall, 1983: Norman, 1992: Schippers, 2000; Grubben and Denton, 2004). Other local names of roselle in Ghana are 'bra' 'bre', and 'bito' in Dagbanli, Dagaare and Frafra languages respectively.

In Ghana, roselle is commonly found in the wild but domesticated cultivars are normally planted as a border crop and/or intercrop with arable crops such as maize and groundnuts. Norman (1992) indicated that it is often intercropped with yams. As a leafy vegetable crop, it is cultivated all year round. ICRA (2002) described roselle as an indigenous leafy vegetable that is considered as a minor crop in the production system and as a result little attention is paid to it in terms of labour and land allocation. It has a variety of uses. The young shoots and leaves and calyces are used in preparing soups .According to Norman (1992); Schippers (2000); and Grubben and Denton (2004) the leaves and young shoots are cooked as spinach in stews and soups and the enlarged succulent red or white acidic calyces are used in thickening soups and in the production of jelly, jam, chutney, syrup and non alcoholic drink .The roselle leaves and calyces are high in ascorbic acid. Grubben and Denton (2004) indicated that the dried red calyces are commonly used to prepare a tea, drunk hot or more commonly, cold after adding sugar. Atta *et al.* (2010) stated that the leaves of roselle have considerable economic importance because of their nutritional and

medicinal uses. Again, Bolade *et al.* (2009) reported that in Nigeria, the production of non alcoholic beverage from dried red roselle calyces is very popular.

There is increasing demand for TLVs due to their health promoting benefits. According to Tindall (1983) they are rich sources of non-glycemic carbohydrates (i.e., dietary fibre) and contain small amounts of omega-3, an essential polyunsaturated fatty acid which the body needs to stay healthy. Drake (1985) added that roselle has many uses in traditional medicine as digestive and purgative agent, healing of abscesses, cancer and hypertension management.

Tarwadi and Agte (2003) explained that most of these leafy vegetables are inexpensive, easily cooked, and rich in several nutrients such as vitamins, proteins and phytochemicals having antioxidant properties. Dari and Mahunu (2010) said green leafy vegetables are herbaceous plants with different shapes which contain essential nutrients for growth and maintenance of the body. Grubben and Denton (2004) reported that the fresh roselle leaves per 100g edible portion contains about 86.6 g water, 180 kJ energy (43kca), 3.3 g protein, 0.3 g fat, 9.2 g carbohydrates, 1.6 g dietary fibre, 213 mg Calcium, 93 mg Phosphate, 4.8 mg Iron, 4135 $\mu$ g  $\beta$ -carotene equivalent, 0.2 mg thiamin, 0.45 mg riboflavin, 1.2 mg niacin, and 54 mg ascorbic acid. The composition of fresh raw calyces per 100 g edible portion contain about 8.2 g water, 184 kJ (44 kcal), 1.6 g protein, 0.1g fat, 11.1 g carbohydrates, 2.5 g fibre, 160 mg calcium, 60 mg phosphate, 3.8 mg Iron, 285  $\mu$ g  $\beta$ -carotene equivalent 0.04 mg thiamin, 0.06 mg riboflavin, 0.5 mg naciان, and 14 mg ascorbic acid.

The use of roselle as a leafy vegetable is important in the preparation of soups common among people from the Northern, Upper East and Upper West regions of Ghana. It is often used along with cereal and tuber- based dishes. There is a popular

saying among Dagombas that “they consider the value or social standing of a visitor before preparing roselle soup for him or her’.

Indigenous leafy vegetables are cheap sources of dietary fibre and other important nutrients essential for good health. It is no wonder that in rural areas TLVs are consumed in greater quantity and the people seem to appear healthier. Roselle plays a great role in the socio-cultural and economic life of many Ghanaians when it comes to the diet, especially for people from the Northern, Upper East and Upper West Regions of Ghana.

Indigenous leafy vegetables play an important role in income generation of most Africans (Schippers, 2000; McClintock, 2004; Ata *et al.*, 2010; and Adebooye, 2011). However, records are hard to come by in terms of extent of production and level of incomes generated as a leafy vegetable. In terms of roselle calyx production, Sudan is the most important roselle producer in Africa with annual area cultivated ranging between 11,000.00 to 57,000.00 ha and exported about 32,000 mt in 1995 (Grubben and Denton, 2004). El Naim *et al.* (2012) stated that roselle is an important cash crop and source of income for small scale farmers in Western Sudan especially in North Kordofan State.

Dry season gardeners always cultivate roselle and uproot the whole plant at three to four weeks old and sell to consumers. By this practice farmers easily run out of seeds of roselle seeds. Consequently, they resort to the use of all kinds of varieties of roselle seeds or its related species which are not very appealing to consumers. Interactions with two dry season farmers groups at Moglaa and Bihinayili communities in the Savelugu/Nantong district of Northern region revealed that they are aware of the ability of regeneration of vegetative growth after harvesting, as harvesting by cutting

is being practiced in amaranthus and corchorus. The reasons were that; it is much better to store roselle when the roots are attached and selling them in bundles, makes accountability easy.

Vegetable seed production in Ghana has not been developed. Norman (2003) and Adebooye *et al.*(2005 lamented that lack of indigenous vegetable seeds in terms of availability and quality is a major limitations for their production. There are several cultivars of roselle which are cultivated throughout Africa and beyond (Norman, 1992).

Little attention is given to research and development of indigenous leafy vegetables in Africa (Norman, 1992; Norman 2003; and Adebooye, 2011).In Norman (1992): Oomen (1964) alluded to the fact that they have rightly been termed a ‘tropical under development’. When roselle is grown as a leafy vegetable close spacing is adopted (Norman 1992; Schippers, 2000 and Diouf *et al.*, 2007). The initial age of harvesting of roselle leaves vary from place to place.

There is therefore, the need to improve on the husbandry practices of roselle in order to maximize its production as a traditional leafy vegetable crop.

Hence, the objectives of this study were to :(i) establish the optimum spacing required for growing roselle as a leafy vegetable, (ii) compare the yield of three roselle cultivars,and (iii) determine appropriate plant age at first harvest for continuous production of roselle as a leafy vegetable.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Roselle Cultivars

There are many different cultivated varieties of roselle. Farmers use a wide variety of cultivars that has been domesticated. In Ghana intensive research has not been done to develop known cultivars or varieties. This is emphasized by (Norman,1992; Norman, 2003; and Adebooye, 2011) that little attention is given to research and development of indigenous leafy vegetables in Africa.

In the area of calyx, seed and fibre production,a lot of research has been done in roselle in Sudan, Senegal, Egypt and other sub-tropical countries to develop improved cultivars.McClintock (2004) reported that in Senegal varieties that are commonly cultivated are red-stems *ruber* and the greenish-yellow *albus*.

According to Schippers (2000) it is very hard to distinguish between kenaf and roselle during the, non-flowering stages. Varieties can be classified into three different colour groups namely: green, green and red and dark-red. The leaves could be shallow incised 3-lobed and deeply 5 or 7 lobed finger-like ones. There are wide differences in petal colour ranging from creamy-white through yellow to orange. Most varieties have yellow flowers with distinct dark-red staminal column, but the stamens of some cultivars are light yellow. There are also structural differences in terms of plant height, canopy spread although these can be altered by the plant spacing. Also,(Shippers, 2000, and Grubben and Denton 2004) indicated that roselle cultivars are self-pollinated and flowering begins when day length decreases at the earliest at two months after sowing and at the latest seven months. The fruits begin to ripen two

to three months after pollination. The three cultivars are propagated by seeds. Germination of seeds takes 4-5 days. Harvesting of matured calyces takes place towards the dry season from October to December.

## **2.2 Harvesting of Roselle as a Leafy Vegetable**

Timely harvesting of a leafy vegetable is very critical. Roselle leaves are harvested and consumed throughout its growth and developmental process. Grubben (1976) reported that cutting or pruning ensures many harvests from the same crop without replanting whereas uprooting allows for several crops of leafy vegetables to be grown within a season. Norman (1992) indicated that vegetables must be harvested at the right time and handled with care. He cautioned that harvesting should not be delayed so that the crop gets over matured in order to maximize profit, since this will affect the quality of the crop. Hence, prompt harvesting of leafy vegetables is essential.

Different methods are employed in the harvesting of roselle leaves. This has implication in estimation of the leaf yield of roselle. Some women utilize the leaves by plucking them from the branches. Different roselle leaf yields are reported by many researchers due to the fact that the leaves are harvested at different stages of growth of the plant. Some farmers broadcast the seeds and harvest the young plants by uprooting them when they are three to four weeks old. While some farmers start harvesting roselle leaves at six weeks onwards with repeated harvests. McClintock (2004) reported that farmers begin to harvest roselle leaves for consumption from six to eight weeks after planting in Senegal and Mali, and harvest the leaves two to three times during its growing period.

A survey conducted in the Northern, Upper East and Ashanti regions of Ghana on roselle, by Obodai (2007) revealed that 29.2% of farmers harvest roselle leaves from

3-4 weeks old, 32.8% 4-6 weeks old, 27.8% from 6-8 weeks old, and 9.7% from 8 weeks; and that 54.7% farmers harvest roselle leaves by uprooting, 27.2% by cutting and 18.1% by plucking of the leaves. Reasons given for uprooting was that, there was scarcity of water to sustain continuous production of roselle by cutting during the dry season, and uprooted plants can be kept fresh much longer than pruned clippings.

Harvesting time can be controlled to optimize the leaf productivity of roselle. According to Maruo *et al.* (2003) and Takataki *et al.*(2003) repeated harvesting is suitable for leafy and shoot vegetables. Again, Takataki *et al.* (2003) stated that amount of residual portion left after cutting affect the growth of the succeeding leaves. Also, Fu (2008) stated that harvesting caused plant branching, leading to an increased leaf numbers and decreased leaf sizes.

In a study of response of roselle to harvesting methods and time of first harvest in the guinea savanna agro-ecological zone of Ghana, Osei-Kwarteng *et al.* (2012) reported that all the parameters studied (plant height, stem girth, number of branches, number of leaves and fresh and dry matter yield) were significantly ( $P < 0.05$ ) affected by the time of first harvest. The first harvest factors were 5, 7, and 9 weeks after planting. They recommended 7 weeks after planting as appropriate time suitable for first harvest of roselle as a leafy vegetable. Apart from plant height, methods of harvesting had no significant ( $P < 0.05$ ) effect on the parameters studied.

### **2.3 Planting and Spacing**

Spacing is crucial in crop production. Norman (1992) and El Naim *et al.* (2012) indicated that in general, as plant density increases per unit area, a level is reached at which plants begin to compete for certain essential growth factors such as nutrients, sunlight, water, oxygen and carbon dioxide.

Norman (1992) on roselle cultivation indicated that, seeds can be sown on the nursery bed or sown direct on the field. On the nursery bed, seeds are broadcast or sown in drills. The seedlings are then planted out on the field when they are 10-20 cm tall at a spacing of 30-45 × 30-45 cm. Seeds propagated by direct seeding on the field are sown 2-3 per hill at the same spacing and later thinned to single plants. Wider spacing of 2 × 2 m is employed for fruit production.

Diouf *et al.* (2007) also reported that roselle sowing in Senegal is mostly done by broadcast by farmers. But spacing of 15-20 cm within rows and 10-15 cm between rows and later thinned at four weeks old after sowing and ends when secondary branches are fully developed. Sowing rate ranged between 15-25kg/ha for roselle which was much higher than the rate of 4-8kg/ha recommended by research.

Schippers (2000) also indicated that one can either broadcast seeds sown, two or three at a time with spacing of about 15 × 15 cm, or alternatively the crop is sown in lines 30 cm apart and later thinned when the plants are 20 cm tall and marketed with their roots attached. Germination takes 7 days, longer than most other vegetables which takes 4-5 days. Spacing for seed production is 60 × 60 cm for calyx production, the crop is sown at a spacing of about 50 × 70 cm, with wider spacing resulting in shorter plants with more branches and more fruits/plant.

Grubben and Denton (2004) also reported that as a leafy vegetable, seeds are either broadcast or dibbled with 3-5 seeds/hole, 2-3 cm deep at an average spacing of 40-60 cm in rows and 60-90 cm between rows. For calyx production, wider spacing of 100 cm apart is adopted.

Adegbite *et al.* (2008) also indicated a spacing of 10 × 25 cm and thinning to one plant per stand.

## 2.4 Effects of Plant Population Density on Growth and Yield of Roselle

According to Krishnamurthy *et al.* (1994) biomass yield of mesta (*Hibiscus sabdariffa* L.) decreases with increase in spacing.

Babatunde *et al.* (2002) research on sowing dates, intra-row spacing and the use of nitrogen fertilizers in roselle production showed that plant height, canopy diameter and the number of branches/plant were significant at  $P < 0.01$ . Among three intra-row spacings;  $60 \times 40$ ,  $60 \times 60$ ,  $60 \times 80$  cm, the intra-row spacing at 80 cm gave the highest values for plant height, canopy diameter, and number of branches per plant.

Obodai (2007) adopted the spacing  $30 \times 30$  cm,  $40 \times 35$  cm and  $45 \times 45$  cm which was within the range recommended by Norman, (1992) in a research she conducted on the effect of methods of establishment and spacing on the growth and leaf yield of roselle. She asserted that spacing did not show any significant effect on the growth parameters (plant height, stem girth, canopy spread, branches and leaves, except on canopy spread. With four harvests,  $45 \times 45$  cm spacing produced a significantly ( $P < 0.05$ ) higher fresh leaf yield/plant than the  $30 \times 30$  cm spacing.

Muoneke and Asiegbu (1997) on okra intercropped with maize indicated that LAI increased with increase in plant density. Muoneke *et al.* (2002) on roselle and cowpea intercrop, reported the highest leaf area with highest planting density of 55,500/ha and Muoneke and Mbah (2007) on cassava intercropped with okra also indicated that LAI increased with highest plant density of 56,000/ha.

Work done in Brazil by Ramos *et al.* (2011) to analyze the effects of plant spacing within rows by incorporating chicken manure with five spacing between plants: 0.30, 0.35, 0.40, 0.45 and 0.50 m with inter-row spacing of 0.5m reported that fresh and dry weight yields of the roselle leaves were significantly influenced by the spacing

between plants and application of chicken manure separately. The biggest fresh and dry weight yields of leaves were recorded with the spacing with 0.30 m between the plants. The smallest fresh and dry weights yields of leaves were recorded at 0.50 m spacing between plants. Although, the individual yield was reduced as competition increased, the higher number of plants per area was worthwhile and resulted in the biggest yield. Leaf area was significantly influenced by the interaction between the spacing and the application of the chicken manure. The largest leaf area/plant was obtained with 0.50 m spacing between plants.

#### **2.4.1 Effects of Plant Population Density on Growth and Yield of other Crops**

Norman (1992) indicated that optimum plant population gives the greatest net returns which every farmer desires.

##### **2.4.1.1 Amaranthus**

Field studies of amaranthus by Enyi (1965) recommended 45cm × 45cm spacing for *Amaranthus oleraceus*. Further studies of Amaranthus by Norman and Shongwe (1993) revealed that the highest plant density by 60 x 45 cm out yielded both fresh weight of shoots and leaves than the widest spacing of 90 x 60 cm in experiment 1. In experiment 2, the 45 x 45 cm spacing also recorded the highest fresh weight shoots and leaves yields than the 90 x 60 cm spacing.. It was also observed that the wider spacings significantly produced more shoots/plant, total shoot, leaf or stem yield/plant, and higher leaf/stem ratios than the closer spacings.

Research conducted by Singh and Whitehead (1993) in: Janick and Simpsons (eds), (1993) on vegetable amaranthus production in wide inter -row of 90 cm with intra-row spacing of 4, 8, 16, 24 and 40 cm reported that the tallest plants were produced in the closer intra-row spacing 4 cm and the widest spacing 40 cm intra-spacing

produced the least plant height. The highest leaf number and maximum leaf area were obtained with the widest spacing. The regressing of the specific leaf weight on intra-row spacing was non-significant indicating that intra-row spacing did not affect leaf thickness. The maximum stem, petiole and leaf fresh weights were produced in the widest spacing and minimum were produced in the closets spacing. On a unit area basis, green yield increased quadratically as intra row spacing decreases. The coefficient of determination  $R^2$  of green yield in intra-spacing was 0.96 indicating 96% of total variation in the mean yield could be explained in the quadratic regression equation. The wider spacing gave a higher stem and leaf fresh weight/plant than the closer spacing. While the closer spacing recorded higher yield ( $\text{kg/m}^2$ ) than the wider spacing. Grubben and Denton (2004) reported that a research in Ghana showed that the highest yield, 50 kg of marketable shoots or 29 kg of edible leaves per  $10 \text{ m}^2$  was obtained with a spacing of 10 x 45 cm.

Mortley *et al.* (1992) indicated that intra-row spacing of amaranth at 10, 20, 30, and 40 cm and inter-row spacing of 62.5 cm, fresh weight yield/plant increased linearly at each successive harvest as spacing increased from 10-40 cm at each harvest up to the third, but declined at the fourth harvest. Total fresh weight/plant across all the four harvest increased linearly from 10 -40 cm spacings. They therefore, concluded that, amaranth can be harvested more than once and fresh weight yield is highest at closer within row than the wider within row.

#### **2.4.1.2 Corchorus**

Field studies on the effects of spacing on yield of Corchorus by Norman and Shongwe (1991) indicated that a spacing of 45 x 10 cm gave the maximum yields of both fresh weight of shoots and leaves than the 45 x 45 cm spacing.

Madakadze *et al.*(2007) working on corchorus with three spacings of 50 × 50, 50 × 30, 50 × 10 cm inter and intra-row spacings respectively and four harvesting frequencies of non-harvesting,7,14 and 21 days interval, observed that leaf area, fresh weight, dry weight and seed yields were significantly higher at closer spacing of 50×10 cm compared to 50 × 30 and 50 × 50 cm.

However, Schippers, (2000) recommended 50 × 50 cm spacing for the production of optimum *Corchorus spp* leaf and seed yield.

#### **2.4.1.3 Celosia**

Olufolaji and Ayodele (1982) field trials on *Celosia argentea* L.by transplanting at 10 x 10 cm, 15 x 15 cm, 20 x 20 cm, 25 x 25 cm, and 30 x 30 cm, and harvesting at 10 cm and 20 cm above ground showed that the highest yield was at 15 x 15 cm spacing at a cutting height of 10 cm.

#### **2.4.1.4 Black jack**

In another research on black jack (*Bidens pilosa*), Norman (1994) reported that closest spacing of 45 × 10 cm produced significantly the lowest number of shoots, the highest total shoot and total fresh leaf weight yields per hectare and lowest total shoot, leaf and stem weight yields per plant. Whilst the widest spacing of 45 × 45 cm gave opposing results of the closest spacing. He explained that the high population density resulted in high rate of competition between the plants for nutrients, water and other resources leading to low yields per plant. However, results on the effects of spacing on the leaf/stem ratios were not consistent but, the widest spacing of 45 × 30 cm gave the highest leaf/stem ratio followed by the two narrower spacings, 45 × 15 cm and 45 × 10 cm, but there were not significantly different from each other.

#### **2.4.1.5 Okra**

In a field studies, Afari (1993) attributed low production of leaves of okra to increase in plant density, where subsequent competition for water, light and nutrient resulted in reduction of production of photosynthate. Muoneke and Asiegbu (1997) and Talukder *et al.* (2003) on okra, reported that high population density of okra promoted stem elongation leading to taller plants. According to Odeleye *et al.* (2005) on okra trials, indicated that lower plant population produced and partition higher dry matter to vegetative and reproductive parts. Similar findings on okra studies have been reported by Ariyo *et al.* (1991); and Muoneke and Mbah (2007).

#### **2.4.1.6 Mung bean**

Sarwar-Jahan and Hamid (2006) demonstrated that yield is the function of total dry matter production which also depends nearly wholly on the canopy photosynthesis and radiation intercepted by the leaf surface and the efficiency of its use in developing biomass govern the dry matter production. The proportion of intercepted radiation is determined by plant architecture which is genetically determined and by the rate at which canopy closes. The rate of canopy development is in turn affected by management practices. In order to hasten canopy closer and increase radiation interception planting density has a large bearing.

### **2.5 Apical dominance and Branching Hypothesis**

So much research has been done on apical dominance and its influence on the outgrowth of axillary buds. Hosokawa *et al.* (1990) explained that apical control is the inhibition of a lateral branch growth by distal shoots and apical control starts when new lateral buds are known to be controlled by the upper shoot dormancy. The outgrowth of lateral buds is known to be controlled by the upper shoot tissues which include the apex, the young leaves and upper stem.

Cline (1997) defined apical dominance as the term used to explain the control of the shoot tip over axillary bud outgrowth. On the other hand Shimizu-Sato *et al.* (2009) described apical dominance as a phenomenon in which a main shoot in an intact plant grows predominantly while suppressing the outgrowth of axillary buds, and that branching has an important role in generating a large variety of diverse plant forms, since the level of apical dominance varies depending on the type of plant species and the age of the plant.

Apical dominance is often best demonstrated through shoot tip decapitation. Auxin plays a key role in apical dominance by the suppression the outgrowth of lateral buds from the terminal bud's apical meristem as it diffuses downward. This however, depends on how active the growing tissue is, since an excess of auxin is growth inhibiting of lateral buds and thereby starving them of important nutrients. It is also stipulated that auxins have an influence on cells around the lateral buds that stimulate them to produce ethylene which also inhibits the outgrowth of lateral buds. Abscisic acid accumulation during aging also suppresses lateral buds growth (Thimann and Skoog, 1934; Cline 1994 and Dun *et al.*, 2006).

According to Ongaro and Ottoline (2008) auxin was the first hormone to be linked to the regulation of shoots branching and when apex of the plant is removed axillary buds that have been dormant become activated and the plant start growing branches. The first experiment conducted to demonstrate this phenomenon with auxin was carried out by Thimann and Skoog (1934).

Cytokinin is observed to be antagonistic to auxin activity by promotion of growth of lateral buds while auxin inhibits. A novel hormone yet to be chemically defined which is said to be carotenoid derived hormone, also inhibits branching. More shoots are

produced when terminal buds are removed giving the plant a bushy shape or form (Cline, 1991, Beveridge *et al.*, 1994; Morris *et al.*, 2001; Dun *et al.*, 2006 and Simons *et al.*, 2007).

Leopold (1964) indicated that the suppression of growth of lateral buds has received greater attention of the role of apical dominance, and that extensive controversies developed around the function of auxin in it, and that, although the locus of the inhibition agrees with the locus of auxin formation and the polarity of the effects matches the polarity of auxin movement in most cases, there are quantitative uncertainties.

Gregory and Veale (1957) on the contrary, refuted that lateral bud inhibition was anything than nutrient competition. They demonstrated that the presence of high auxin concentrations limit or prevent the development of lateral vascular strands; and this is done by denying the lateral buds of nutrients.

Went (1938) reported that with more elaborate interpretations of the mechanism whereby auxins inhibit lateral bud development has been made. It has also been postulated that certain substances other than auxin necessary for bud growth are diverted to regions of relatively high auxin concentration such as terminal buds and that lateral buds fails to develop because of a lack of these substances in adequate quantities. One such suggestion is that caulocaline is considered important for stem elongation might move primarily to regions of maximum auxin synthesis such as the apical buds.

According to Leopold (1949) and Gordon (1957) that there is no rational basis which can account for all instances of apical dominance as a result of auxin control, and in the entire plant other forces must be involved in this correlation effect. But, there is no

question that auxin participates in apical dominance; in addition to the evidence that it can replace the inhibiting action of the apex, there is evidence that conditions which lower the endogenous auxin content of the plants do correlate with the development of lateral buds.

Dun *et al.* (2006) argued that branches of undisturbed plants with active shoot tip growth are generally not essential for the life cycle of the plant, but rather serve to promote vegetative growth and/or to generate multiple sites for seed production. Excessive branching may be expensive, therefore branching, of intact plants is likely to be carefully modulated in response to environmental factors such as light quality, nitrogen and carbon availability, and growth and development of other plant parts.

The stipulation of different hypothesis of branching control may be due to different experimental systems and techniques rather than divergent mechanisms of control between species (Dun *et al.*, 2006). Three hypothesis of branching revolves around the plant hormone auxin. The Classical hypothesis states that auxin acts to regulate shoot branching in concert with other signals such as cytokinin (Hall and Hillman, 1975; Morris, 1977 and Bangerth, 1989).

The auxin transport hypothesis postulates that axillary bud out growth is regulated by auxin transport as opposed to the actual quantity of auxin (Bangerth, 1989; Li and Bangerth, 1999; and Leyser, 2005).

While the bud transition hypothesis proposes that the bud may reside at least in three developmental stages; a stage of dormancy, a stage of transition, or stage of sustained growth (Strafstrom and Sussex, 1992; Napoli *et al.*, 1999 and Morris *et al.*, 2005).

Schimizu-Sato *et al.* (2009) indicated that shoot branching has an important role in generating a large variety of diverse plant forms, because the degree of apical dominance varies with plant species.

### **2.5.1. Pruning**

Pruning is the careful removal of plant parts. It is not only restricted to the stems but also to the root systems of plants, flowers and fruits. Reasons assigned to pruning include the following ;(a) to prevent or delay flowering and encourage vegetative growth e.g. Amaranthus ,celosia (b) to encourage vegetative growth ( more lateral growth e.g.Amaranthus,Carnations,Celosia,etc. (c) to reduce excess flower number in order to increase flower size,e.g.Carnations,rose,etc.(d) to trim roots and leaves of some species prior to planting out.(e) to control diseases and pests,and (f) to rejuvenate the plant (Norman,2004).Various forms of pruning exist, namely heading back and thinning out. Heading back involves the removal of the terminal portion of shoots, which stimulates the growth of branches (breaks) from dormant buds below the cut on the remaining portion of the shoot, thereby breaking apical dominance. The net effect of heading back is a compact, dense or much-branched type of vegetative growth. Pinching is heading back of actively growing plants, which normally involves the removal of the apical meristem to facilitate branching. On the other hand, thinning out embraces the removal of the entire shoot, hence, encouraging apical dominance in plants promoting open type of growth. Disbudding is the removal of flower buds on a single stem and leaving the central flower bud to develop into a large flower head, e.g. Celosia, Carnations and roses (Norman, 2004).

### **2.6. Effect of Apical Pruning on vegetative Growth**

Edmond *et al.* (1977) stated that removal of apical dominance through stopping or pinching, water, and minerals are diverted to the lateral dominant buds below the cut

and this promotes the growth of many lateral shoots. According to Janick (1979) available research information on many unrelated species of crops, the removal of the apical portion of the stem leads to increased vegetative development, promote dry matter accumulation and reduced plant height. This might be due to changes in the balance between root and shoot. Topping, greatly changes the root-to-shoot balance and the result of diversion of water, nutrients and stored food from the intact root system to a reduced bud area is the flush of growth which is normally seen.

### **2.6.1 Roselle**

Most roselle cultivars by nature produce many branches in the intact form. Norman (1992) reported that bushy cultivars of roselle exist. Schippers (2000) indicated that growing roselle as a ratoon crop, when the plant is four weeks old, and topping is done about 6-8 cm from the soil level or just about the third leaf, it stimulates the development of two to three side shoots from which leaves could be harvested after another 2-3 weeks interval. Harvesting of roselle leaves starting from 6-8 weeks after sowing stimulate branching leading to increase in leaf production (Grubben and Denton, 2004). McClintock (2004) reported that in Senegal and Mali farmers harvest roselle leaves two to three times during the growth period which increases the number of flowering shoots.

### **2.6.2 Amaranthus**

Studies of two determinate (early-flowering) and indeterminate (late-flowering) cultivars of *Amaranthus cruentus* by Olufolaji and Tayo (1989) in: Norman (1992) investigating their performance under two harvesting methods showed that pruning produced more leaves and branches, total fresh weight yield and dry weight of the various plant parts than uprooting the plant. Norman (1992) reported that regrowth

after topping of amaranthus can provide up to four harvests per crop, although not all cultivars are suitable for topping.

Field experiments by Norman and Shongwe (1993) to study the time of initial topping, spacing, cutting height and harvesting frequency on amaranth revealed that initial topping of plants at 2 WAP resulted in the production of more shoots but a reduction in both fresh and dry shoot yields than plants topped at 5 WAP.

### **2.6.3. Other crops**

In a related study on Black jack (*Bidens pilosa*), Norman (1994) illustrated that topping the plants at 2 WAP significantly increased the total number of shoots per plant, total fresh and dry shoots and leaf yields. However, total stem dry weight was not influenced by topping. The leaf/stem ratio of topped plants was higher than that of plants which were not topped early.

Repeated harvesting of Corchorus by pruning produced a higher number of branches and shoot and leaf yield than uprooting the plant (Schippers, 2000). Field trials investigating the effect of stem cutting and seed yields of *Corchorus olitorius* L. by Ahmed and Oladiran (2012) showed that the number of branches was significantly higher in plants that were cut than uncut plants. Grubben and Denton (2004) indicated that cutting of Corchorus stimulates the development of side shoots.

Harvesting of Water leaf, *Talinum triangulare* (Jacq.) by cutting facilitate the development of new lateral shoots (Norman, 1992 and Schippers, 2000).

Kutor (2008) on the studies of the effect of topping and spacing on the growth and flowering of Celosia (*Celosia cristata*), reported that topped plants had outnumbered the control in the number of leaves, and also increased vegetative development but

reduced plant height. Oti (2009) on *Celosia* also reported that topped plants produced more side shoots and heavier stem fresh weight than control plants.

In a study of the effect of apical pruning and spacing on the growth and yield of Okra, Wenyonu *et al.* (2011) reported that pruning significantly increase the canopy area, number of branches, number of leaves, leaf area and leaf area index, however, these values decreased with subsequent prunings. Pruning treatments on Legon Spineless produced taller plants than Legon Fingers with plant height decreasing with subsequent pruning for both cultivars.

### **2.7 Effect of Apical pruning on yield.**

In general research findings of several species of leafy vegetable crops, pruning by the removal of the terminal bud improved yield of crops, since many side shoots may be developed.

#### **2.7.1 Roselle**

Grubben (1977) indicated that from duration of 120-180 days growing period, many harvests mean leaf yield of 16 t/ha of roselle could be achieved. Grubben and Denton (2004) reported on roselle that for leafy branches yield of up to 20.0t/ha from three cuttings is obtainable.

Obodai (2007) indicated that four harvests of roselle leaves were made as a result of harvesting by pruning. The 30 x30 spacing recorded higher marketable yield (175.95t/ha) than the 45 x 45 cm (62.81t/ha).

#### **2.7.2 Effect of apical pruning on yield of other crops**

A lot of research works have been done on the influence of pruning on the growth and vegetative yield of *amaranthus* and *corchorus*.

### **2.7.2.1 Amaranthus**

Norman and Shongwe (1993) investigating time of initial topping, spacing, cutting height and harvesting frequency on amaranth reported that plants that were initially topped at 5 weeks after planting (WAP) significantly outyielded (35.84t/ ha, 25.02t /ha) in terms of fresh weights of shoots and leaves respectively, than those which were initially topped at 2 WAP (30.39t /ha, 21.02t /ha), fresh weights of shoots and leaves respectively. However, topping of plants at 2 WAP resulted in the production of more shoots than the 5 WAP. The plants that were initially pruned at 5 WAP produced a significantly higher leaf/stem ratio than those initially pruned at 2 WAP.

Field studies of vegetable amaranth by Mnsava and Masam (1985) revealed that total leaf and seed yield increased with initial topping heights and were positively and significantly correlated with total plant dry weight.

### **2.7.2.2 Other crops**

Although, harvesting by cutting of *Corchorus* showed that the number of leaves from each harvest increases, it was accompanied with a reduction in size and weight, and a fall in consumer appeal of recovered leaves (Akoroda and Olufajo, 1981).

Field trial of Black jack (*Bidens pilosa* L.) on effect of topping, spacing, cutting height and harvesting frequency, Norman (1994) revealed that pruning recorded 46.76t/ha as compared to 37.89 t/ha on fresh leaf yield of topped, and no topped Black jack yields respectively. Leaf/stem ratios on dry weight basis also showed 2.07 for topping as compared to 1.96 for no topping treatments.

With water leaf harvesting, many succeeding harvests up to 20 could be made on new lateral shoots which developed as a result of pruning of terminal shoots, and harvested shoots yield of 20-30t/ha could be achieved (Norman, 1992).

Studies on okra by Wenyonu *et al.*, (2011) showed that pruning significantly enhanced the production of more branches, increased leaf number, increased total leaf area and leaf area index thereby promoting canopy size but reduced final plant height.

## **CHAPTER THREE**

### **3.0 MATERIALS AND METHODS**

#### **3.1 Experimental Site**

Field and pot experiments were carried out at the University of Ghana farm, Legon located ( $05^{\circ} 39' N, 0^{\circ} 11' W$ ) in the Greater Accra region from 25 June, 2012 to 25 February, 2013. The site falls within the Adenta series (FAO/UNESCO, 1990) and classified as Ferric Aerisol. The profile of the top soil is sandy loam and made up of about 20 cm of pale brown-to-brown sand with weak fine granular structure and has a loose and friable consistency. The area has coastal savannah vegetation with bimodal rainfall pattern with mean annual rainfall of 112.0 mm and temperature of 32°C.

#### **3.2 Source of Seeds and Selection of Roselle cultivars**

Seeds of three local roselle cultivars namely Moglaa 1 (Mogla1), Moglaa 2 (Mogla 2) and Bihinayili (Bihi) were used in the experiments. They were obtained from Moglaa and Bihinayili farming communities in the Savelugu/Nangton District of the Northern region of Ghana. The previous unknown roselle cultivars were named after the communities in which they were collected for the study. This attests to the fact that there is still little or no research to improved indigenous important leafy vegetables in Ghana and West Africa as a whole (Norman, 1992; Norman, 2003; and Adebooye, 2011). Hence, there is undocumented information about them. A meeting was organized with farmers and agricultural extension agents to help identify some of the types of roselle cultivars that are commonly grown in the areas as leafy vegetable crop.

### **3.2.1 The Mogla 1 Cultivar**

This cultivar is an annual herb up to 1.65 m in height with reddish stems and petioles. The leaves are dark -green shallowly incised 3-4 lobes. It produced bright –yellow flowers with canopy spread of 50-65 cm<sup>2</sup> .The green calyx is much fleshy than the Bihi cultivar.

### **3.2.2 The Mogla 2 Cultivar**

This is also a branched annual herb up to 1.45m in height with reddish stems and petioles. The leaves are also dark-green shallowly incised 3-5 lobes. The fresh calyx is more fleshy and bigger than the Mogla 1 and the Bihi cultivar. It produced bright-yellow flowers with canopy spread of 50-70 cm<sup>2</sup> .

### **3.2.3 Bihi Cultivar**

The Bihi cultivar is an annual herb growing to 1.87m high with greenish stems and petioles. The leaves are green and more incised than the Mogla 1 and Mogla 2 with 4-5 lobes. The Bihi cultivar produces less fleshy calyx as compared to the Mogla 1 and Mogla 2 cultivars.

## **3.3 Climatic data**

Table 1 indicates data on climatic conditions during the period of the experiments. Total amount of rainfall during the period of the study was 426.3mm. The rainfall was quite erratic during the field experiment and the total rain days were 46. There was no much variation in the relative humidity and temperature. Mean monthly sunshine ranged from 4.8 to 8.5 hours.

**Table 1: Climatic data during the study period June,2012 to February,2013**

Month	Total Rainfall (mm)	No.of Rain Days	Relative Humidity		Temperature (°C)		Mean monthly Sunshine Duration (hrs)
			At 09:00 h GMT	At 15:00 h GMT	Max.	Min.	
<b>June</b>	173.2	14	89	78	30.3	23.7	4.8
<b>July</b>	20.9	5	86	68	28.8	23.1	5.3
<b>August</b>	11.5	4	86	67	28.2	22.4	5.0
<b>September</b>	42.5	12	86	67	30.0	23.2	5.9
<b>October</b>	88.3	5	89	67	31.2	23.8	7.8
<b>November</b>	14.0	1	88	63	32.4	24.6	8.5
<b>December</b>	41.9	3	91	66	32.6	24.9	7.5
<b>January</b>	34.0	2	90	88	33.4	25.5	7.5
<b>February</b>	0.0	0	93	66	33.7	25.4	8.5

**Source: Ghana Meteorological Services Agency, Mempeasem, Legon**

### 3.4 Field Experiment

The field experiment was conducted at the University of Ghana farm, Legon. The crop was in field for 73 days from 25 June, 2012 to 6 September, 2012.

#### 3.4.1 Experimental Design and Layout

The experimental design for the field experiment was a 4 × 3 factorial arranged in a randomized complete block design with 4 replications. The factors were 4 spacings and 3 roselle cultivars. The spacing treatments were: 30cm × 30cm, 30cm × 35cm, 30cm × 40cm, and 30c × 45cm. The three local cultivars were Moglaa 1, Moglaa 2 and Bihinayili. Total experimental units were 48 with the size of each plot as 1.7m×1.9m (3.23m<sup>2</sup>) and separated from each other by 0.50m with a border of 0.50m created around the treatment plots. The blocks were separated by a space of 1.0 m. There were 5 rows per plot but the number of plants per row varied with the spacing.

The 30c × 30cm and 30cm x 35cm spacings had 6 and 5 plants per row respectively, while the 30cm x 40cm and the 30c x 45cm spacings had 4 plants per row. Few plants per row were used due to limited seeds.

### **3.4.2 Agronomic practices**

#### **3.4.2.1 Land Preparation and Sowing**

The land was ploughed on June 15, 2012 and harrowed after one week. Seeds were sown directly 2-3 cm deep with 5 seeds per hole on June 26, 2012. The seedlings were later thinned to two plants per stand at two weeks old.

#### **3.4.2.2 Fertilizer Application**

A compound fertilizer, (N.P.K., 15-15-15) was applied by ring placement at a recommended rate of 300 kg/ha (Norman, 1992). This was done two weeks after planting. Sulphate of ammonia was applied at the rate of 125 kg/ha (Norman, 1992).

Side dressing with the sulphate of ammonia was split applied at 50% at 32 days after first harvest. The fertilizer was applied 5 cm deep and 5 cm away from the plants.

#### **3.4.2.3 Weed Control**

Weeds were controlled with hoeing at two weeks intervals starting two weeks after sowing. Occasional hand pulling of weeds was also done. Hoeing was also done to improve soil aeration and facilitate water penetration into the soil.

#### **3.4.2.4 Watering**

Although the experiment was conducted during the major rainy season, the rainfall was quite erratic (Table 1). Supplementary irrigation was therefore, done with the use of a watering can once every two days.

### 3.4.2.5 Pests and Diseases Control

The field was regularly monitored for identification of diseases and insect pests.

Cydim Super, an emulsifiable concentrate with 36g cypermethrin and 400g dimethoate per litre was applied at the rate of 2 ml/litre with 15-litre knapsack sprayer two weeks after germination to control important insect pests identified on the field during the period of the study such as flea beetle (*Podagrica sjostedii*), variegated grasshopper (*Zonocerus variegatus*), cotton stainer (*Dysdercus supersticiosus*), aphids (*Aphis* spp), white flies (*Bemisia tabaci*), asparagus beetle (*Crioceris asparagi*), crickets and caterpillars. LEVO 2.4SL, a botanical insecticide was also used to control spider mites (*Tetranychus urticae*) at 5 ml/15 litres of water using knapsack sprayer when the infestation rate was high especially at 25 DAS. Hand picking and crushing of insect pests was occasionally done. Damping off disease was observed in few seedlings during the first week after seedling emergence.

## 3.5 Pot Experiment

The pot experiment was conducted at the University of Ghana farm, Legon, from 26 September, 2012 to 25 January, 2013.

### 3.5.1 Experimental Design and Layout

The experimental design was 2×3 factorial arranged in a randomized complete block design with 3 replicates. The treatments were two local roselle cultivars, Moglaa 1 and Bihinayili and three different ages at first harvest: 31, 38 and 45 DAS. The initial harvesting was done with the use of secateurs to cut the main stem at 13.0 cm high. Each replicate contained six experimental units with seven pots representing each unit. The total number of pots was one hundred and twenty six with forty- two pots

per replication. The pots were separated from each other by 0.20 m and a space of 1.0 m created between each block.

### **3.5.2 Soil Preparation and Pot Filling**

Plastic pots of 4.5 litre capacity measuring 19.0 cm high, 22.0 cm at the top and 15.1 cm at the base were used for the experiment. Three drainage holes were perforated at the bottom of each plastic pot. The growth media that was used for the study was a mixture of top soil, river sand and decomposed cattle manure in the ratio 2:1:1 by volume. The top soil was dark-brown collected under decomposed vegetation under mango trees. The soil belongs to the Adenta series. Dry grass 15.0 cm thick was spread on the bulked soil samples of top soil and river sand. Fire was set on the dried grass as a means of using dry heat in sterilizing the soil to kill some weed seeds, nematodes and other possible soil pathogens and pests. Burning to some extent partially sterilizes the soil (Norman, 2004). The sterilized soil sample was left overnight to cool and mixed with well decomposed cattle manure before filling the pots. About 3.0 cm space of the plastic pots was left for watering purposes.

Norman (2004) indicated that for pots of 13cm and above, 3-4cm must be left for watering. The mixture was watered and allowed to drain for three days to attain field capacity before sowing the seeds. The weight of the growth media for each pot was 4.0 kg. For each cultivar, five seeds were sown per pot at the depth of about 2 to 3cm on 26 September, 2012. Germinated seeds were thinned to 2 plants per pot at 2 weeks after sowing.

### **3.5.3. Weed Control**

Weeds were controlled first with the use of hand fork, and occasionally by hand picking within the pots after seedling emergence. Hand forking helped improve soil

aeration. Two weekly hoeing was done to control weeds found between the pots and the 1.0 m space created between each block.

#### **3.5.4 Fertilizer Application**

N.P.K15-15-15 compound fertilizer was applied at the rate of 6.0g per pot two weeks after planting. Side dressing with 3.0g sulphate of ammonia in split application was done, with 50% applied at 32, 40, or 47 days respectively after first harvest depending on the type of treatment. The remaining 50% was applied at 52, 60 and 67 DAS respectively. The fertilizer was applied 5 cm deep and 5 cm away from the plants.

#### **3.5.5 Pests and Diseases Control**

Cydim Super, an emulsifiable concentrate with 36g cypermetrin and 400g dimethoate per litre, was applied at the rate of 2 ml/litre with 15-litre knapsack sprayer to control insect pest.

Hand picking and crushing of insect pests was occasionally done. LEVO 2.4SL, a botanical insecticide was used to control spider mites at 5 ml/ 15 litres of water using the knapsack sprayer. Pot plants were monitored for early detection and control of insect pests and diseases. Few leaf spots were observed on old ageing leaves close to the soil level.

#### **3.5.6 Watering**

Watering was done with the use of the watering can after every two days. About 0.71 litres of water was applied per pot.

### **3.6 Data Collection**

Data were collected on the following parameters on five record plants of the two inner rows in the field experiment and five record plants in the pot studies as follows:

### **3.6.1 Date of Sowing**

The date of sowing for both the field and pot experiment was recorded.

### **3.6.2 Number of Days to Seedling Emergence**

The number of days taken for seedlings to emerge was also recorded.

### **3.6.3 Plant Height**

Plant height was measured at 31 days after sowing (DAS) in the field experiment and depending on the type of treatments in the case of the pot experiment when pruning started. After the initial harvest, measurement of new shoots length was repeated every two weeks at every harvest. The height of the plants was taken from the soil level to the highest tip of the shoot of the plant. Heights of new shoots were taken from the base of the main stem. A meter rule was used to record the plant height.

### **3.6.4 New Stem Diameter**

The regenerated stem diameter was also measured at 5 cm away from the main stem using Vernier caliper and the mean calculated.

### **3.6.5 Leaf Number Per Plant**

Leaf number was taken. This was done by counting the number of leaves per record plant at first harvest at 31 DAS and repeated every two weeks before each harvest for the field experiment, but in the case of the pot experiment, time of counting of leaves at first harvest depended on stipulated plant age at first harvest ( PAFH) and subsequently repeated every two weeks before each harvest and the mean computed.

### **3.6.6 Number of Shoots per Pplant**

The number of shoots per plant was determined by counting the number of shoots that appeared on the plant at 31 DAS and repeated every two weeks before each harvest

for the field experiment. With the pot experiment, counting of the number of shoots started before harvest depending on the type of treatments of PAFH and repeated every two weeks before each harvest and the mean computed.

### 3.6.7 Leaf Area

Leaf area was also determined at each harvesting stage. This was done with the use of cork borer method (Addo-Quaye *et al.*, 2011; and Jombo *et al.*, 2012). Five fresh leaf discs were punctured out with a cork borer of radius 0.9cm. The fresh weight of the leaf discs were determined by the use of an electronic balance. Leaf area of each slice disc shaped leaf was calculated as follows:

Area ( $A$ ) =  $\pi r^2$ , Total area of fresh leaf discs was equal to the total number of leaf discs multiplied by the area of one of the leaf discs calculated. Total harvested leaves fresh weight was determined using the electronic balance.

By proportionality method; Total leaf area of freshly harvested leaves = Total leaf discs area ( $\text{cm}^2$ ) x Total harvested leaf fresh weight (g)/ Total leaf disc fresh weight (g)

### 3.6.8 Leaf Area Index (LAI)

The Leaf Area Index (LAI) for the field experiment only was calculated by dividing the leaf area per plant by land area occupied by each plant adopting the method of Watson (1952) and Bréda (2003).

### 3.6.9 Number of days to flower bud appearance

In the pot experiment, plants were observed and the number of days to flower bud appearance recorded and the mean determined for each treatment.

### **3.7 Post-Harvest Data**

#### **3.7.1 Number of harvested flower buds per plant**

The Number of flower buds per plant per harvest was recorded by counting and the mean computed for each treatment in the pot experiment.

#### **3.7.2 Determination of fresh and dry weights**

The initial harvesting was done with the use of a secateur to cut the main stem at 13.0 cm high. Harvesting was done in the mornings between 6:00 am and 9.00am. Subsequent harvest was done every two weeks up to four harvests for the field experiment and seven harvests for the pot experiment. Only four harvests were made in the field experiment due to lack of rains and break down of water pumping machine at the University of Ghana Farm, Legon. Five record plants were harvested and separated into various components of stems, petioles and leaves (leaf blade). Fresh weights were taken using electronic beam balance to weigh each sample separately. The components were put into labeled brown envelopes and dried at 70° C for 72 hours to constant weight using an electronic oven (Norman and Sichone, 1993). The dry weights of each sample were recorded using electronic beam balance at the Department of Crop Science of the University of Ghana-Legon.

#### **3.7.3 Fresh weight of flower buds**

The fresh weight of flower buds was taken at each harvest in the second experiment by the use of electronic balance and the mean computed

#### **3.7.4 Dry weight of flower buds.**

The dry weight of flower buds was taken by the use of electronic balance and the mean weights computed

### **3.7.5 Number of harvested leaves per plant**

The number of harvested leaves per plant was determined by counting the number leaves harvested per plant per harvest and total mean number computed.

### **3.7.6 Fresh weight of leaves**

The fresh weight of harvested leaves was recorded by the use of electronic balance and the mean weights computed.

### **3.7.7 Dry weight of leaves**

The dry weight of leaves was recorded with electronic balance and mean weights calculated.

### **3.7.8 Number of harvested stems per plant**

The number of harvested stems per plant was determined by counting and the mean computed.

### **3.7.9 Fresh weight of stems**

The fresh weight of stems was recorded by the use of electronic balance and the mean weights computed.

### **3.7.10 Dry weight of stems**

The dry weight of stems was recorded by the use of electronic balance and the mean weights calculated

### **3.7.101 Fresh weight of petioles**

The fresh weight was recorded by the use of electronic balance and the mean computed.

### **3.7.11 Dry weight of petioles**

The dry weight of petiole was also recorded by the use of electronic balance and the mean computed.

**3.7.12 Number of unmarketable leaves**

Leaves with more than 50% of area covered by holes, mechanical damage and senesced leaves were counted and recorded at each harvest in the pot experiment.

**3.7.13 Leaf fresh weight per plant**

The leaf fresh weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total leaf fresh weight (g) /plant.

**3.7.14 Leaf dry weight per plant**

The leaf dry weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total leaf dry weight (g)/plant.

**3.7.15 Petiole fresh weight per plant**

The petiole fresh weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total petiole fresh weight (g) /plant.

**3.7.16 Petiole dry weight per plant**

The petiole dry weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total petiole dry weight (g) /plant

**3.7.17 Stem fresh weight per plant**

The stem fresh weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total stem fresh weight (g) /plant.

**3.7.18 Stem dry weight per plant**

The stem dry weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total stem dry weight (g) /plant.

### **3.7.19 Shoot fresh weight per plant**

The shoot fresh weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total shoot fresh weight (g) /plant.

### **3.7.20 Shoot dry weight per plant**

The shoot dry weight per plant at each harvest was computed as cumulative weight for the period of the harvest to obtain the total shoot dry weight (g) /plant.

### **3.7.21 Leaf fresh yield per hectare**

Leaf fresh yield/ha was calculated by multiplying yield/plant by land area occupied by each plant and yield/ha was calculated using proportionality ratio and the mean computed for the field experiment.

### **3.7.22 Leaf dry yield per hectare**

Leaf dry yield per plant at each harvest was calculated and proportionality ratio used to compute the leaf dry yield per hectare (t/ha).

### **3.7.23 Stem fresh yield per hectare**

Stem fresh yield per plant at each harvest was calculated and proportionality ratio used to compute the stem fresh yield per hectare (t/ha).

### **3.7.24 Petiole fresh yield per hectare**

Petiole fresh yield per plant at each harvest was calculated and proportionality ratio used to compute the petiole fresh yield per hectare (t/ha).

### **3.7.25 Shoot fresh yield per hectare**

Shoot fresh yield per plant at each harvest was calculated and proportionality ratio used to compute the shoot fresh yield per hectare (t/ha) for the field experiment.

### **3.8 Allometric Ratios**

The ratio between leaf blade/stem, petiole/leaf blade, and leaf/Shoot both (fresh and dry weight basis) was calculated by dividing the total leaf blade weight by total stem weight, total petiole weight by total leaf blade, and total leaf weight by total shoot weight respectively on both fresh and dry weight basis.

### **3.10 Statistical Analysis**

Analysis of variance (ANOVA) for the data collected was done using Genstat software (version 9.2). Where significant differences between treatment means were observed, the least significant differences (LSD) at  $P=0.05$  was used to separate the means. Standard error bars and LSD bars were used to show level of significance among the treatments for the bar charts and line graphs respectively.

### **3.11 Correlation matrix**

Relationship among some parameters using correlation matrix was done. The parameters used in the field experiment included average new shoot length, leaf area index at first harvest, leaf area index at last harvest, leaf area at first harvest, leaf area at last harvest, leaf fresh yield (t/ha), plant height at first harvest, total shoot fresh weight/plant, total shoot dry weight/plant, total leaf number/plant, total leaf dry weight/plant, total leaf fresh weight/plant, total shoot number/plant, total harvested leaf number/plant. The correlation for the pot experiment however, excluded leaf area index and leaf fresh yield (t/ha).

## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Field Experiment

##### 4.1.1 Vegetative Growth

##### 4.1.1.1 Plant height at harvest

Table 2 illustrates plant height at harvest at 31 DAS. There was significant difference in plant height of cultivars, spacing and interactions between the cultivar and spacing. The Bihi cultivar was taller than Mogla 1 and Mogla 2 cultivars. The 30cm x 30cm spacing produced the tallest plants. There were no significant differences in plant height between 30cm x 35cm, 30cm x 40cm and 30cm x 45cm spacings. The Bihi interactions with 30cm x 30cm spacing produced taller plants than 30c x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. There were no significant differences between 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings interactions with the Bihi cultivar.

**Table 2: Influence of spacing of three roselle cultivars on plant height (cm) at first harvest**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	32.7	23.4	23.3	26.5
30 x 35	30.2	23.3	21.3	24.9
30 x 40	29.9	25.3	25.3	25.2
30 x 45	30.5	23.1	19.62	24.4
Mean	30.8	23.8	21.2	

LSD (P= 0.05); Cultivar = 0.89 ,Spacing = 1.03,Cultivar x Spacing = 1.78

#### 4.1.1.2 Mean length of new shoots at harvests

Table 3 shows mean length of new shoots at harvests. There were significant differences between the following: cultivar, spacing, and interaction between cultivars and spacing. The Bihi cultivar had the longest mean new shoots length at all spacings. The closest spacing, 30cm x 30cm produced longer mean new shoots length than 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. The interactions between the Bihi and 30cm x 30cm spacing also produced longer mean new shoot length.

**Table 3: Influence of spacing of three roselle cultivars on mean length (cm) of shoots for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	16.77	13.83	13.72	14.77
30 x 35	15.34	12.97	12.14	13.48
30 x 40	16.48	12.86	12.99	14.11
30 x 45	14.81	12.18	11.35	12.78
Mean	15.85	12.96	12.55	

LSD (P=0.05); Cultivar = 0.29 Spacing = 0.33, Cultivar x Spacing = 0.58

#### 4.1.1.3 Mean diameter of new stem at harvests

The mean new stem diameter at harvests are presented in table 4 below. There were no significant differences in the following: cultivar, spacing, and interactions between the cultivar and the spacing.

**Table 4: Influence of spacing of three roselle cultivars on mean new stem diameter (mm) at harvests**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	3.43	3.13	3.47	3.34
30 x 35	3.38	3.30	3.14	3.28
30 x 40	3.33	3.43	3.49	3.42
30 x 45	3.45	3.47	3.40	3.44
Mean	3.40	3.33	3.38	

LSD (P=0.05); Cultivar = NS, Spacing = NS, Cultivar x Spacing = NS

#### 4.1.1.4 Total leaf number/plant before harvesting

Table 5 illustrates total leaf number/plant before harvesting. There was no significant difference in total leaf number /plant between Bihi, Mogla 1, and Mogla 2 cultivars. Spacing and interaction between cultivar and spacing had a significant effect on total leaf number/plant. There were no significant differences in total leaf number /plant between 30cm x 35cm and 30 x 40cm spacings. The 30cm x 30cm spacing interaction with Mogla1 cultivar produced higher number of leaves/plant than 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. The least number of leaves/plant were produced by interaction Bihi cultivar with 30cm x 45cm spacing.

**Table 5: Influence of spacing of three roselle cultivars on total leaf number before harvesting for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	211.0	226.0	205.0	214.0
30 x 35	209.0	200.0	201.0	203.0
30 x 40	206.0	198.0	196.0	200.0
30 x 45	184.0	195.0	202.0	194.0
Mean	203.0	205.0	201.0	

LSD (P=0.05);Cultivar = NS,Spacing = 6.90,Cultivar x Spacing = 11.95

#### 4.1.1.5 Total new shoots number/plant

There were significant differences in total new shoots number/plant in the following: cultivar spacing, and interactions between cultivar and spacing for the period of the harvests. However, there was no significant difference in total new shoots number/plant between Bihi and Mogla 2 cultivars at 30cm x30cm and 30 x 40cm spacings, and the 30cm x 35cm and 30cm x 45cm spacings. The Mogla 1 cultivar produced more new shoots at 30cm x 30 cm spacing than the Bihi and the Mogla 2 cultivars (Table 6).

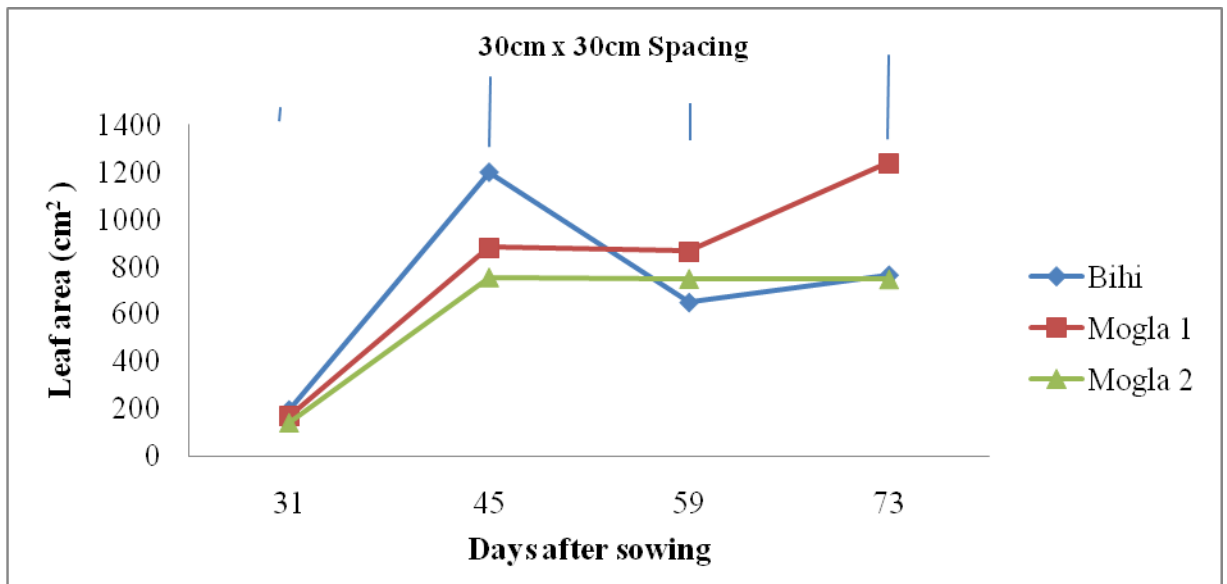
**Table 6: Influence of spacing of three roselle cultivars on total new shoots number/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	30.0	35.0	30.0	32.0
30 x 35	31.0	31.0	31.0	31.0
30 x 40	32.0	33.0	31.0	32.0
30 x 45	30.0	31.0	31.0	31.0
Mean	31.0	33.0	31.0	

LSD (P=0.05); Cultivar = 0.80, Spacing = 0.92, Cultivar x Spacing = 1.60

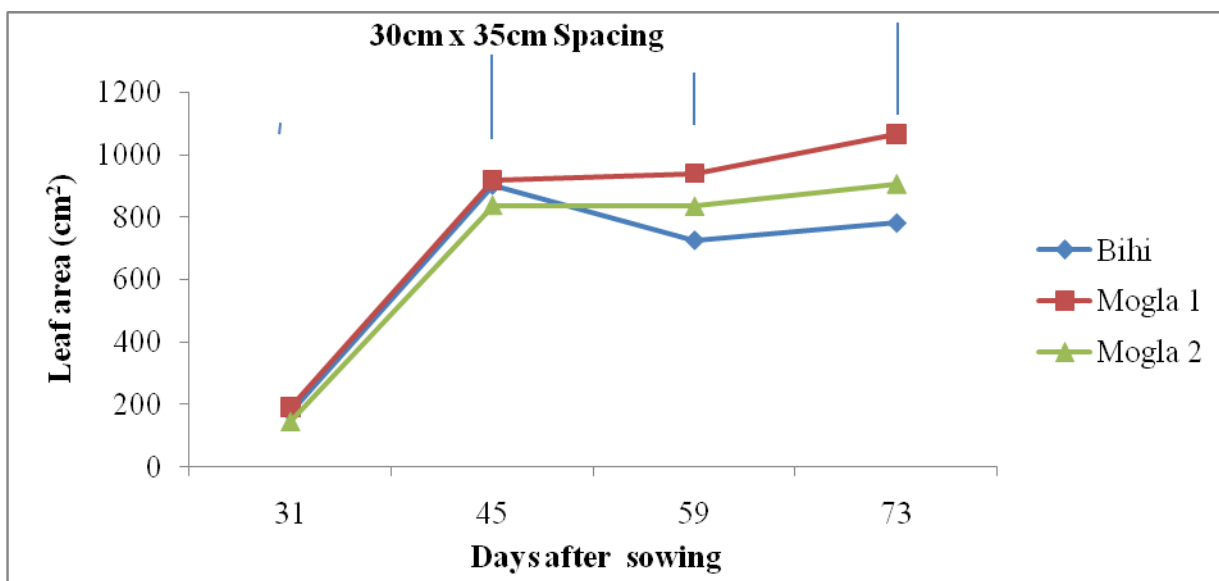
#### 4.1.1.6 Leaf area/plant (cm<sup>2</sup>) at harvest

Figure 1 illustrates leaf area/plant at fortnightly interval of harvest. At 30cm x 30cm spacing the Bihi cultivar produced a higher leaf area/plant compared to Mogla 1 and Mogla 2 at 31 DAS and peaked at 45 DAS but sharply declined from 45 DAS to 59 DAS, and slightly rose to the end of the experiment at 73 DAS. At 30 x 30 cm spacing the Mogla 1 had higher leaf area/plant more than Bihi and Mogla 2 at 59 DAS and produced higher leaf area/plant at 73 DAS than Mogla 2 and Bihi cultivars. Interactions between the three cultivars and spacing at 30 x 30 spacing did not cause any significant effect in leaf area at first, second and third harvests except in the fourth harvest with the Mogla 1 cultivar (Fig.1).



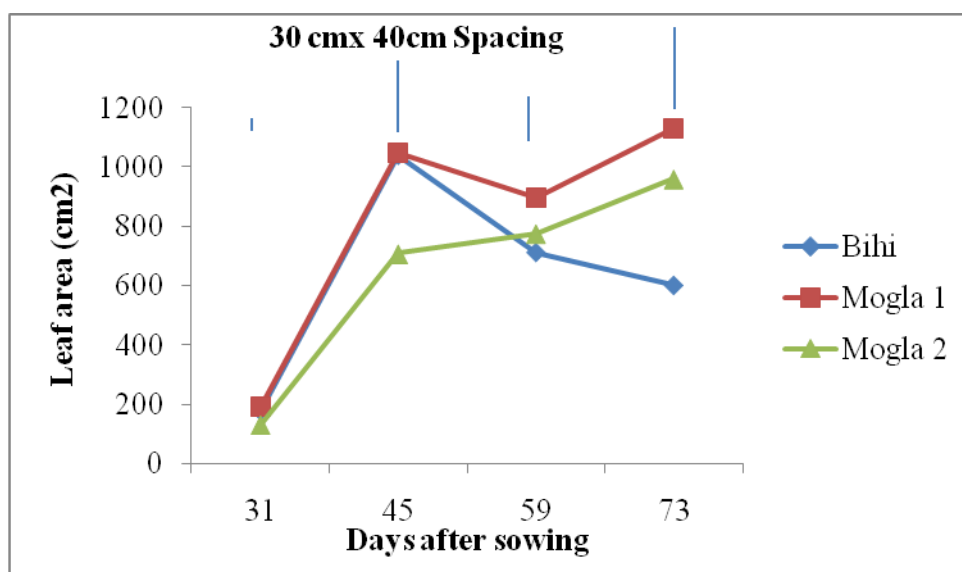
**Figure 1: Influence of spacing of three roselle cultivars on leaf area/plant at 30cm x 30cm spacing**

Mogla 1 recorded a higher leaf area/plant at 31 DAS compared to Bihi and Mogla 2 at the 30 x 35 cm spacing, and slightly increased at 59 DAS and peaked at 73 DAS. Mogla 2 leaf area/plant fairly constantly increased and slightly decreased at 59 rose throughout the experiment. While Bihi declined from 45 DAS to 59 DAS and fairly constantly increased throughout the experiment. There were no significant differences in leaf area between Bihi, Mogla 1 and Mogla 2 interactions with spacing(Fig.2).



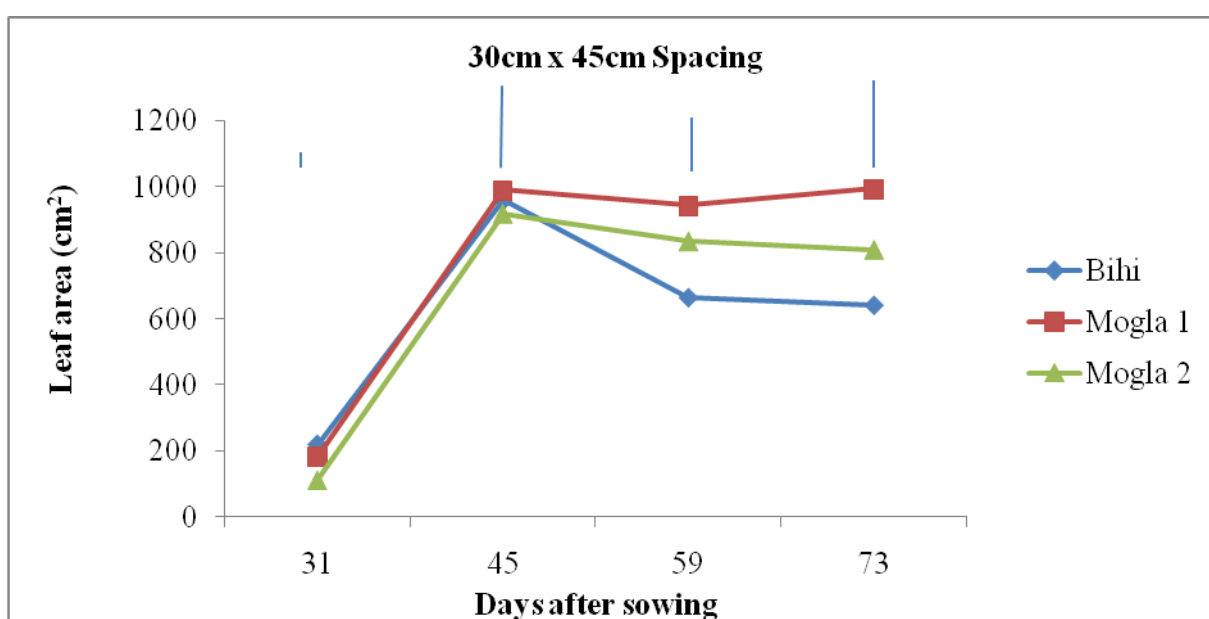
**Figure 2: Influence of spacing of three roselle cultivars on leaf area/plant at 30cm x 35 cm spacing**

Mogla 1 recorded a higher leaf area/plant at 31 DAS compared to Bihi and Mogla 2 with the 30c x 40cm spacings, and declined from 45 DAS to 59 DAS and peaked at 73 DAS. The Bihi sharply declined from 45 DAS up to the end experiment. The 30cm x 40cm spacing did not significantly affect leaf area between the three cultivars (Fig.3).



**Figure 3: Influence of spacing of three roselle cultivars on leaf area/plant at 30cm x 40 cm spacing**

The Bihi cultivar leaf area/plant declined from 45 to 59 DAS and continued with a near constant rate to the end of the experiment. Mogla 1 cultivar recorded a higher leaf area/plant at 31 DAS compared to Bihi cultivar and Mogla 2 cultivar at the 30 x 45cm spacings, and declined from 45 DAS to 59 DAS and peaked at 73 DAS. However there were no significant differences between the three cultivars at 30cm x 45cm spacing (Fig.4).

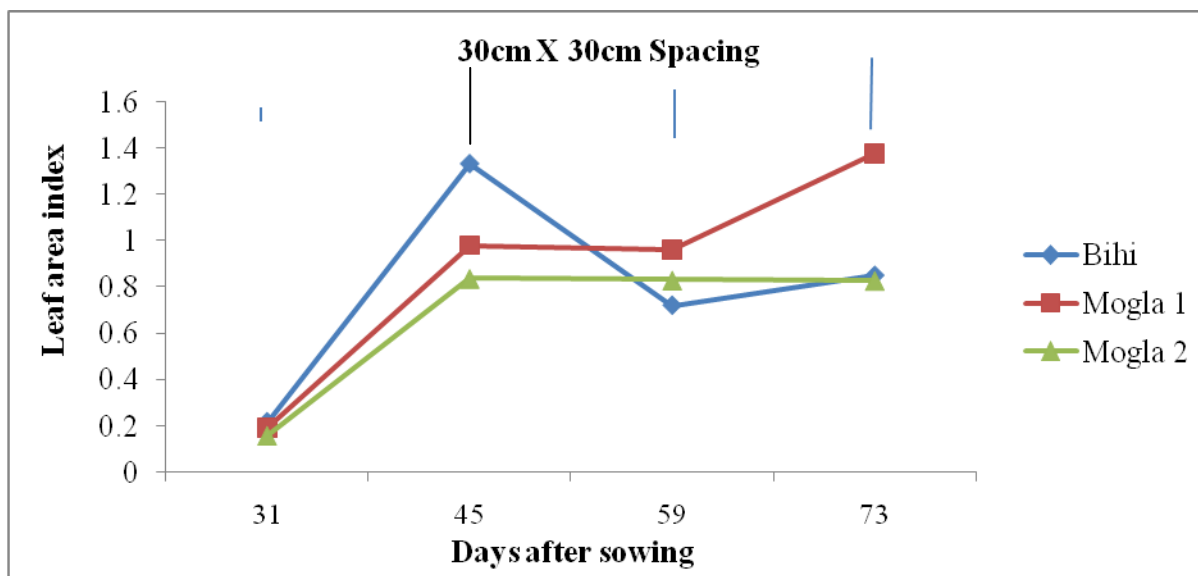


**Figure 4: Influence of spacing of three roselle cultivars on leaf area/plant at 30cm x 45cm spacing**

#### 4.1.1.7 Leaf area index (LAI) at harvest

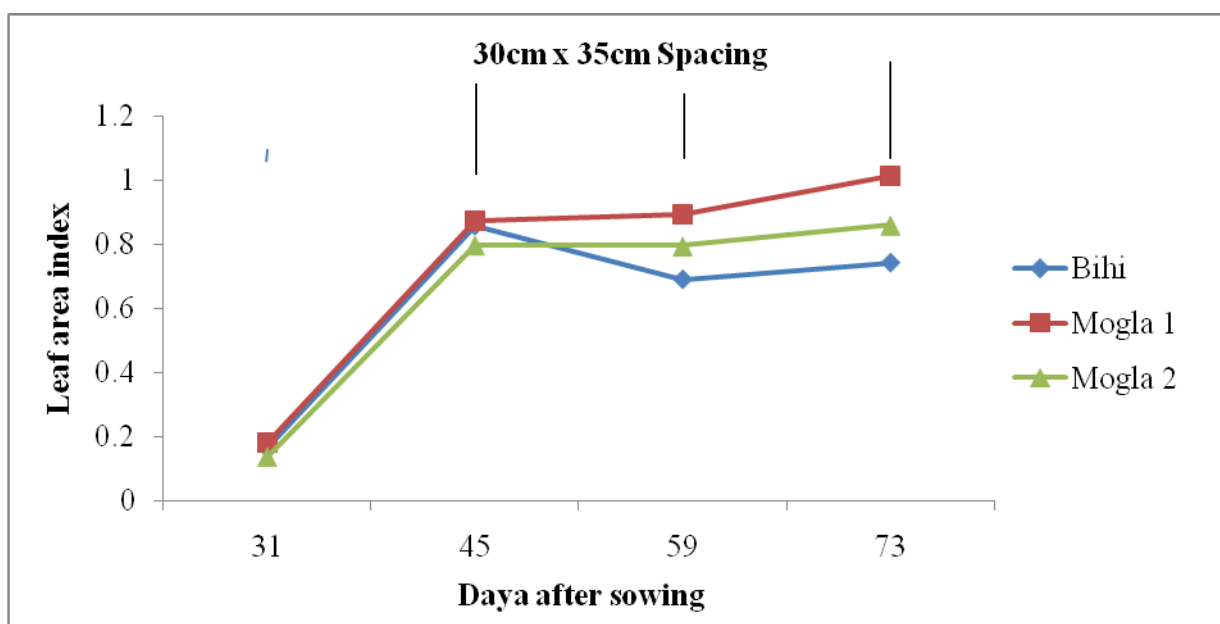
The Bihi cultivar recorded a higher LAI at first harvest at 31 DAS compared with Mogla 1 and Mogla 2 and peaked at 45 DAS at the 30cm x 30cm spacing and the highest plant density, but sharply declined from 45 to 59 DAS. The Mogla 1 had a relatively constant increase from 45 to 59 DAS, and sharply rose and peaked at 73 DAS at 30cm x 30cm spacing, while the Mogla 2 relatively constantly increased from

45 DAS till the end of the experiment. Interactions between the three cultivars and spacing at 30 x 30 spacing did not cause any significant difference in LAI at first, second and third harvests except in the fourth harvest with the Mogla 1 cultivar (Fig.5)



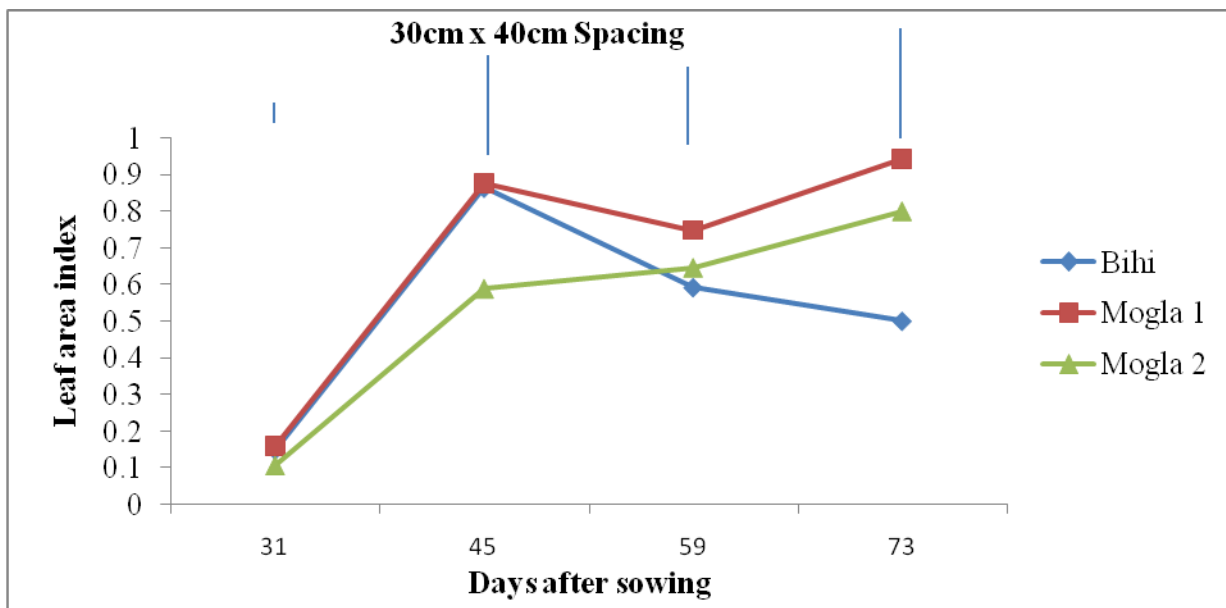
**Figure 5: Influence of spacing of three roselle cultivars on leaf area index/plant at 30cm x 30cm spacing**

The Mogla 1 yielded a higher LAI at 31 DAS compared to Bihi and Mogla 2 with the 30 x35 cm spacing and peaked at 73 DAS. The Bihi LAI sharply declined from 45 DAP to 59 DAS and slightly increased throughout the experiment. The Mogla 2 relatively constantly increased from 45 DAS 59 DAS and slightly increased throughout the experiment. There were no significant differences in LAI between Bihi, Mogla 1 and Mogla 2 and 30cm x 35cm spacing (Fig.6)



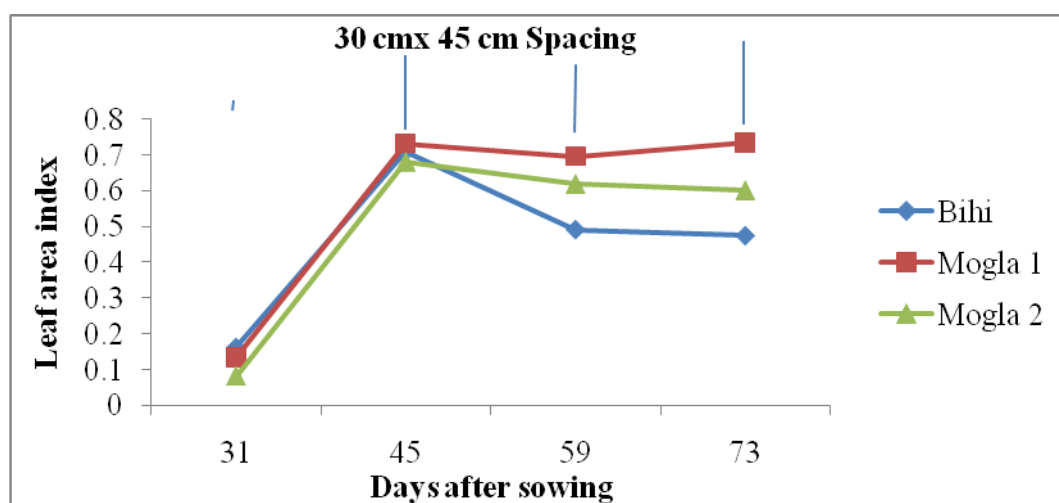
**Figure 6: Influence of spacing of three roselle cultivars on leaf area index/plant at 30cm x 35cm spacing**

The Mogla 1 cultivar yielded a higher LAI at 31 DAS compared to Bihi and Mogla 2 cultivars at 30cm x 40cm spacing and peaked at 73 DAS. LAI in Bihi cultivar sharply declined from 45 DAS to 59 DAS and subsequently slightly increased till the end of the experiment. The Mogla 2 cultivar showed a gradual increase from 45 DAS to the end of the experiment. The 30cm x 40cm spacing interactions with the three cultivars did not significantly affect LAI (Fig.7).



**Figure 7: Influence of spacing of three roselle cultivars on leaf area index/plant at 30cm x 40cm spacing**

The Mogla 1 cultivar recorded a higher LAI at 31 DAS compared to Bihi and Mogla 2 cultivars with the 30cm x 45cm spacing and peaked at 73 DAS. The Bihi LAI sharply declined from 45 DAS to 59 DAS and leveled off to the end of the experiment. The Mogla 2 decreased from 45 DAS to the end of the experiment. The 30cm x 45cm spacing interactions with the three cultivars did not significantly affect LAI (Fig.8).



**Figure 8: Influence of spacing of three roselle cultivars on leaf area index/plant at 30cm x 45cm spacing**

## 4.2 Yield and Yield components

The yield mainly consisted of harvested shoots and yield components comprised harvested leaves (leaf blade), petioles, and stems.

### 4.2.1 Total fresh weight of harvested shoots/plant

Table 7 shows total shoot fresh weight(g)/plant. There were significant differences between the cultivars. Mogla 1 recorded greater shoot fresh weight compared to Bihi and Mogla 2 cultivars. There were no significant differences between Bihi and Mogla 2. There were no significant differences in spacing, and interactions between the roselle cultivars and the various spacings.

**Table 7: Influence of spacing of three roselle cultivars on total fresh shoot weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	94.80	110.90	93.40	99.70
30 x 35	100.80	114.70	98.40	104.70
30 x 40	99.60	112.20	96.30	102.70
30 x 45	99.10	117.90	105.30	107.50
Mean	98.60	113.90	98.40	

LSD (P=0.05); Cultivar = 8.94, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.2 Shoot fresh yield (t/ha)

There were significant differences in total shoot fresh yield (t/h) in cultivar and spacing. The Mogla 1 cultivar gave a greater shoot fresh yield than Bihi and Mogla 2 cultivars. There were no significant differences between Bihi and Mogla 2 cultivars. The closer spacing, 30cm x 30cm recorded a higher fresh shoot yield (t/ha) than the 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. Also there were no significant differences between 30cm x 40cm and 30cm x 45cm spacings. There were no significant differences between the interactions of the cultivars and spacings (Table 8).

**Table 8: Influence of spacing of three roselle cultivars on shoot fresh yield (t/ha)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	10.53	12.32	10.38	11.08
30 x 35	9.60	10.92	9.39	9.97
30 x 40	8.30	9.35	8.03	8.56
30 x 45	7.34	8.74	7.80	7.96
Mean	8.94	10.33	8.90	

LSD (P=0.05); Cultivar = 0.87, Spacing = 1.00, Cultivar x Spacing = NS

#### 4.2.3 Total dry weight of harvested shoots/plant

There was significant difference in total dry weight/plant of harvested shoots in cultivars. The Mogla 1 recorded a higher total shoot dry weight/plant than Bihi and Mogla 2 cultivars. There were no significant differences in spacing, and interactions between the roselle cultivars and the spacing (Table 9).

**Table 9: Influence of spacing of three roselle cultivars on total dry shoot weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	15.63	17.48	14.43	15.85
30 x 35	16.33	18.19	14.57	16.37
30 x 40	16.44	17.29	16.66	16.80
30 x 45	15.96	17.80	16.98	16.91
Mean	16.09	17.69	15.66	

LSD (P=0.05); Cultivar = 1.42, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.4 Total number of harvested leaves/plant

There were no significant differences in total number of harvested leaves/plant for the following; cultivar, spacing, and interactions between cultivar and spacing (Table 10).

**Table 10: Influence of spacing of three roselle cultivars on total number of harvested leaves/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	119.0	119.0	125.0	121.0
30 x 35	130.0	126.0	131.0	129.0
30 x 40	123.0	128.0	123.0	125.0
30 x 45	126.0	132.0	137.0	131.0
Mean	125.0	126.0	129.0	

LSD (P=0.05) Cultivar = NS, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.5 Total leaf fresh weight/plant

Table 11 shows total leaf fresh weight for the period of the harvests, where there were no significant differences in spacing, and interactions between cultivar and spacings. Cultivar significantly affected total leaf fresh weight/plant for the period of the harvests with Mogla 1 having a higher total leaf fresh weight/plant than Bihi and Mogla 2 cultivars.

**Table 11: Influence of spacing of three roselle cultivars on total leaf fresh weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	55.60	67.70	54.40	59.20
30 x 35	58.90	70.20	60.30	63.10
30 x 40	58.00	70.40	55.50	61.30
30 x 45	58.20	72.10	64.00	64.80
Mean	57.70	70.10	58.50	

LSD (P=0.05); Cultivar = 5.88, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.6 Leaf fresh yield

Cultivar, and spacing significantly affected leaf fresh yield (t/ha) with Mogla 1 cultivar recording a higher leaf fresh yield than Bihi and Mogla 2 cultivars. The 30cm x 30cm spacing recorded a higher total leaf fresh yield t/ha than 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. There were no significant differences between interactions of cultivar and spacing (Table12).

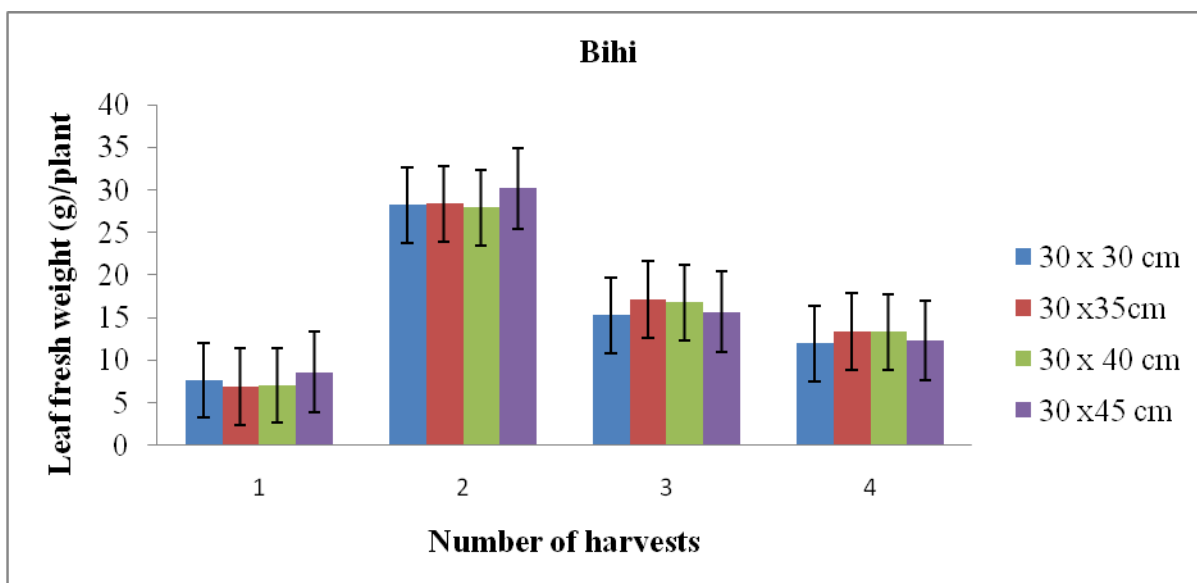
**Table 12: Influence of spacing of three roselle cultivars on leaf fresh yield (t/ha)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	6.17	7.52	6.04	6.58
30 x 35	5.61	6.69	5.74	6.01
30 x 40	4.84	5.86	4.63	5.11
30 x 45	4.31	5.34	4.74	4.80
Mean	5.23	6.35	5.29	

LSD (P=0.05);Cultivar = 0.56,Spacing = 0.65,Cultivar x Spacing = NS

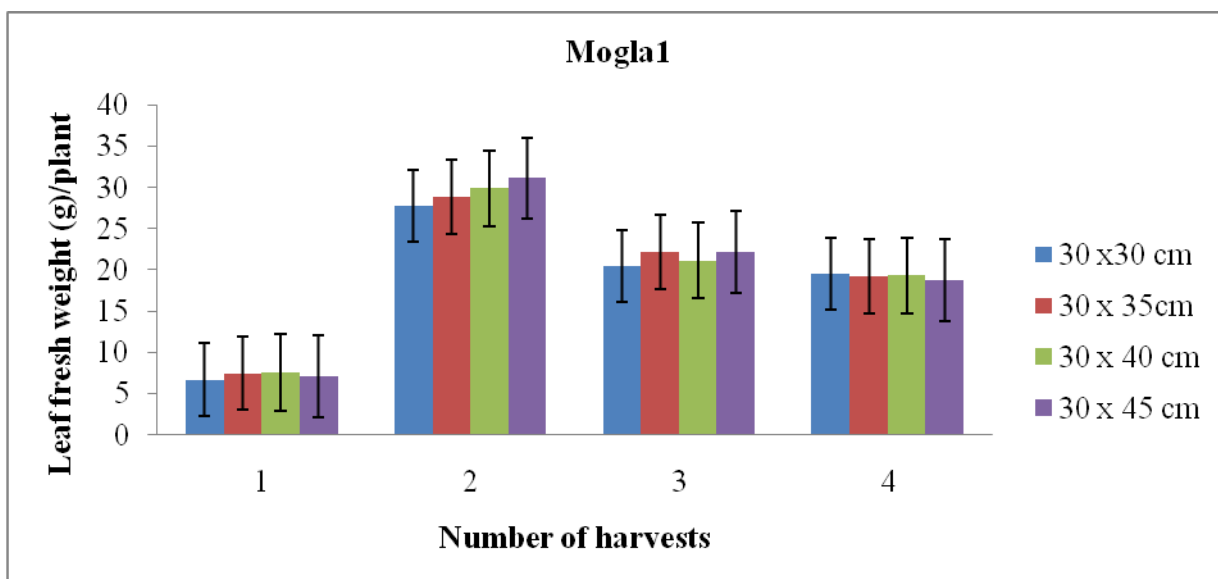
#### 4.2.7 Trend of leaf fresh weight/plant

Bihi cultivar sharply increased in leaf fresh weight/plant after harvesting at 31 DAS, it peaked at the second harvest and declined sharply from the second harvest to the third harvest and decreased till the end of the experiment at 30cm x 45cm spacing. Bihi cultivar interactions with the 30cm x 45cm spacing at second harvest showed significant differences, but there were no significant differences between the 30cm x 30cm, 30cm x 35cm and 30cm x 40cm. There were no significant differences in interactions between Bihi and spacings at the first harvest (Fig.9)



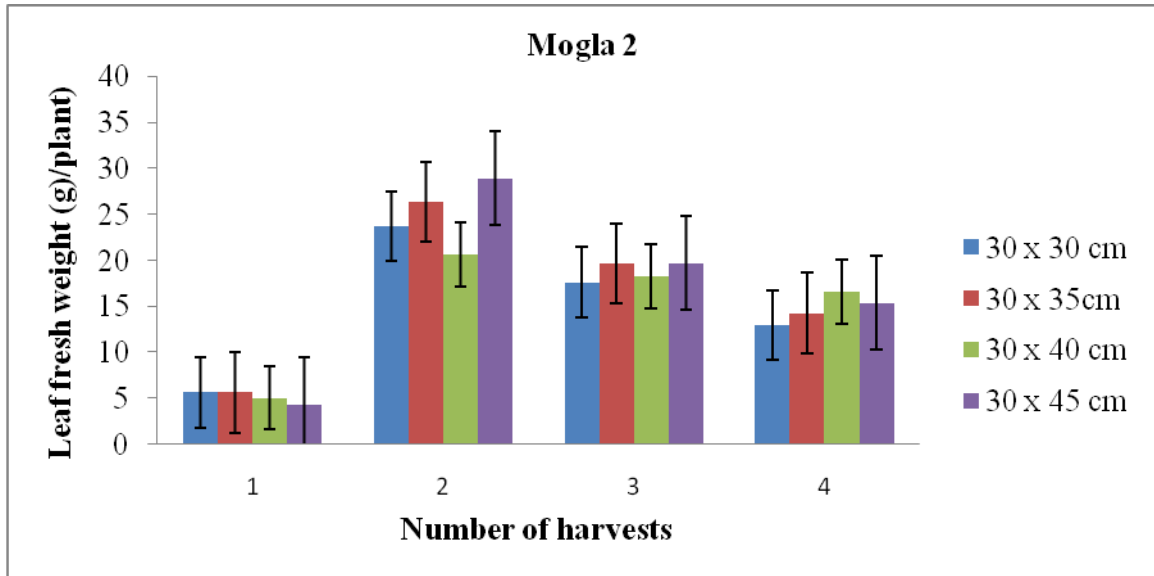
**Figure 9: Harvesting trend of influence of spacing of three roselle cultivars on leaf fresh weight (g)/plant**

Mogla 1 cultivar indicated a sharp increase in leaf fresh weight/plant after harvesting at 31 DAS (fig 10), peaked at the second harvest and declined sharply from the second harvest to the third harvest and further decreased in leaf fresh weight/plant throughout the experiment with 30cm x 45cm spacing. Interactions between cultivar and spacings were not significant.



**Figure 10: Harvesting trend of influence of spacing of three roselle cultivars on leaf fresh weight (g)/plant**

Mogla 2 cultivar sharply increased in fresh leaf fresh weight/plant after the first harvesting at 31 DAS, peaked at the second harvest and declined sharply from the second harvest to the third harvest and continued with decreasing leaf fresh weight/plant to the end of the experiment with all the spacings. Interactions between cultivar and spacing at 30cm x 45cm spacing produced significantly higher fresh leaf weight/plant at the second harvest than the rest of the spacings (Fig.11).



**Figure 11: Harvesting trend of influence of spacing of three roselle cultivars on leaf fresh weight (g)/plant**

#### 4.2.8 Total leaf dry weight/plant

There were no significant differences in total leaf dry weight/plant in the following; spacing, and interactions between cultivar and spacings. Cultivar significantly affected total leaf dry weight/plant, with Mogla 1 cultivar having a higher total dry leaf weight compared to Bihi and Mogla 2 cultivars, but there were no significant differences in total leaf dry weight/plant between Bihi and Mogla 2 cultivars (Table 13).

**Table 13: Influence of spacing of three roselle cultivars on total leaf dry weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	9.18	10.37	8.20	9.25
30 x 35	9.16	11.15	8.31	9.54
30 x 40	8.99	10.35	9.79	9.71
30 x 45	8.80	10.66	10.01	9.82
Mean	9.03	10.63	9.08	

LSD (P=0.05); Cultivar = 0.89 Spacing, Cultivar x Spacing = NS

#### 4.2.9 Leaf dry yield

Table 14 illustrates leaf dry yield t/ha for the period of harvests. There were significant differences in cultivar, and spacing. The Mogla 1 cultivar recorded a higher leaf dry yield compared to Bihi and Mogla 2, while the 30cm x 30cm spacing recorded a greater dry leaf yield than 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. There were no significant differences between 30cm x 40cm and 30cm x 45cm spacings. Again, there were no significant interaction effects on leaf dry yield (t/ha) for cultivar and spacing interaction.

**Table 14: Influence of spacing of three roselle cultivars on leaf dry yield (t/ha)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	1.02	1.15	0.91	1.02
30 x 35	0.87	1.06	0.79	0.90
30 x 40	0.74	0.86	0.81	0.80
30 x 45	0.65	0.79	0.74	0.72
Mean	0.82	0.96	0.81	

LSD (P=0.05); Cultivar = 0.08, Spacing = 0.10, Cultivar x Spacing = NS

#### 4.2.10 Total harvested stem numbers/plant

Cultivar, spacing and interactions between cultivar and spacing did not significantly affect harvested stem numbers/plant (Table 15).

**Table 15: Influence of spacing of three roselle cultivars on total harvested stem numbers/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	21.0	22.0	32.0	25.0
30 x 35	22.0	22.0	24.0	23.0
30 x 40	21.0	24.0	22.0	22.0
30 x 45	22.0	23.0	24.0	23.0
Mean	22.0	23.0	25.0	

LSD (P=0.05); Cultivar = NS, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.11 Total harvested stem fresh weight/plant

Table 16 shows total harvested fresh stem weight /plant for the period of harvesting with no significant differences in cultivar, spacing, and interactions between cultivar and spacing.

**Table 16: Influence of spacing of three roselle cultivars on total fresh stem weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	25.86	25.04	25.04	26.07
30 x 35	27.21	25.21	25.21	26.85
30 x 40	27.91	25.70	25.70	26.17
30 x 45	26.97	26.00	26.00	27.19
Mean	26.99	27.23	25.49	

LSD (P=0.05); Cultivar = NS, Spacing = NS, Cultivar x Spacing = NS

#### 4.2.12 Total stem fresh yield

Table 17 illustrates total fresh stem yield (t/ha) in which there were no significant differences in cultivar, and interactions between cultivar and spacing. There was significant difference in stem fresh yield between spacings. The 30cm x 30cm spacing recorded a greater stem fresh yield than 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings. There was no significant difference between 30cm x 40cm and 30cm x 45 cm spacings.

**Table 17: Influence of spacing of three roselle cultivars on total stem fresh yield (t/ha)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	2.87	3.03	2.78	2.89
30 x 35	2.59	2.67	2.40	2.55
30 x 40	2.32	2.07	2.40	2.18
30 x 45	1.99	2.11	1.92	2.01
Mean	2.44	2.47	2.31	

LSD (P=0.05); Cultivar = NS, Spacing = 0.32, Cultivar x Spacing = NS

#### 4.2.13 Total stem dry weight/plant

There were no significant differences in total dry stem weight/plant in between cultivars, spacings, and interactions between cultivar and spacing (Table 18).

**Table 18: Influence of spacing of three roselle cultivars on total stem dry weight (g)/plant for the harvest period**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	3.84	4.13	3.66	3.87
30 x 35	4.04	3.73	3.71	3.82
30 x 40	4.57	3.72	4.01	4.10
30 x 45	4.04	4.24	3.79	4.03
Mean	4.12	3.95	3.79	

LSD (P=0.05); Cultivar =NS, Spacing = NS, Cultivar x Spacing = NS

### 4.3 Allometric Ratios

#### 4.3.1 Mean leaf blade/stem ratio (fresh weight basis)

Table 19 illustrates mean leaf blade/stem ratio on fresh weight basis for the period of the harvest. Cultivar significantly affected mean leaf blade/stem ratio with Mogla 1 cultivar producing higher leaf blade/stem on fresh weight basis than Bihi and Mogla 2 cultivars. There was no significant difference between Mogla 1 and Mogla 2 cultivars. There were no significant differences in mean leaf/blade ratio with spacing, and also for interactions between cultivar and spacing.

**Table 19: Influence of spacing of three roselle cultivars on mean leaf blade/Stem ratio (fresh weight basis)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	2.51	2.92	2.76	2.73
30 x 35	2.45	2.69	2.80	2.65
30 x 40	2.37	3.14	2.93	2.82
30 x 45	2.41	2.85	2.60	2.62
Mean	2.44	2.90	2.77	

LSD (P=0.05); Cultivar = 0.21, Spacing = NS, Cultivar x Spacing = NS

#### 4.3.2 Mean leaf blade/stem ratio (dry weight basis)

Table 20 shows mean leaf blade/stem ratio on dry weight basis. There were significant difference between Bihi, Mogla 1 and Mogla 2 cultivars. Mogla 1 produced a high leaf blade/stem ratio in terms of dry weight basis than Bihi and Mogla 2 cultivars. There were no significant differences between Mogla 1 and Mogla 2 cultivars. Spacing and interactions between cultivar and spacing was also not significant.

**Table 20: Influence of spacing of three roselle cultivars on mean leaf blade/Stem ratio (dry weight basis)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	2.70	2.85	2.86	2.80
30 x 35	2.69	3.37	2.66	2.91
30 x 40	2.13	3.32	2.74	2.73
30 x 45	2.44	2.75	3.02	2.74
Mean	2.49	3.07	2.82	

LSD ( $p=0.05$ ); Cultivar = 0.31, Spacing = NS, Cultivar x Spacing = NS

#### 4.3.3 Mean leaf/shoot ratio (fresh weight basis)

Mean leaf/shoot ratio significantly affected cultivar, with Mogla 1 cultivar recording higher mean leaf/shoot ratio on fresh weight basis than Bihi and Mogla 2. There was significant difference between Bihi and Mogla 2. There were no significant differences in spacing, and interactions between cultivar and spacing (Table 21)

**Table 21: Influence of spacing of three roselle cultivars on mean leaf/shoot ratio (fresh weight basis)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	0.72	0.75	0.73	0.73
30 x 35	0.73	0.75	0.74	0.74
30 x 40	0.71	0.77	0.73	0.74
30 x 45	0.72	0.75	0.75	0.74
Mean	0.72	0.76	0.74	

LSD ( $P=0.05$ ); Cultivar = 0.01, Spacing = NS, Cultivar x Spacing = NS

#### 4.3.4 Mean leaf/shoot ratio (dry weight basis)

There was no significant difference in mean leaf/shoot ratio in spacing. Cultivar and interactions between cultivar and spacing significantly affected mean leaf/shoot ratio on dry weight basis. Mogla 1 cultivar gave higher mean/shoot ratio (dry weight basis) than Bihi, and Mogla 2 cultivars. There were significant differences between Bihi and Mogla 2 cultivars. The interactions between Mogla 1 cultivar and 30cm x 35cm spacing produced higher mean leaf/shoot ratio (dry weight basis) followed by Mogla 1 and 30cm x 40cm spacing. There were no significant differences in interactions between Bihi, and Mogla 2 at 30cm x 30cm and 30cm x 35cm spacings (Table 22).

**Table 22: Influence of spacing of three roselle cultivars on mean leaf/shoot ratio (dry weight basis)**

Spacing (cm)	Cultivar			Mean
	Bihi	Mogla 1	Mogla 2	
30 x 30	0.75	0.76	0.74	0.75
30 x 35	0.75	0.79	0.74	0.76
30 x 40	0.72	0.78	0.75	0.75
30 x 45	0.74	0.76	0.77	0.76
Mean	0.74	0.77	0.75	

LSD (P=0.05); Cultivar = 0.01, Spacing = NS, Cultivar x Spacing = 0.01

#### 4.4 Relationship among some parameters of roselle in the field experiment

Table 23 illustrates relationships among some of the parameters studied using correlation matrix. Considerable number of the correlation coefficient (r) of the

parameters measured were significant ( $p = 0.05$ ) and some significant at ( $p = 0.01$ ). Stronger association was between total leaf fresh weight/plant and total shoot fresh weight/plant ( $r = 0.94$ ) followed by total leaf dry weight/plant and total shoot dry weight/plant ( $r = 0.93$ ). Other parameters that showed strong associations included fresh leaf yield (t/ha) and leaf area at first harvest ( $r = 0.74$ ), plant height at first harvest and leaf area index at first harvest ( $r = 0.86$ ), total leaf fresh weight/plant and fresh leaf yield ( $r = 0.71$ ), and total leaf fresh weight/plant and total leaf number per plant ( $r = 0.79$ ).

**Table 23: Correlation matrix (r) among some parameters of roselle in the field experiment**

	MNSL	LAIFH	LAILH	LAFH	LALH	FLY	PHFH	TSFWP	TSDWP	TLNP	TLDWP	TLFWP	TSNP	THLNP
<b>MNSL</b>														
<b>LAIFH</b>	0.41*													
<b>LAILH</b>	-0.18*	0.35*												
<b>LAFH</b>	0.34*	0.84**	0.10*											
<b>LALH</b>	-0.34*	0.16*	0.92**	0.10*										
<b>FLY</b>	0.05*	0.65**	0.74**	0.38**	0.57**									
<b>PHFH</b>	0.86**	0.40**	-0.20*	0.47**	-0.26*	-0.01*								
<b>TSFWP</b>	-0.09*	0.37**	0.45**	0.51*	0.54**	0.67**	0.01*							
<b>TSDWP</b>	-0.02*	0.15*	0.43**	0.28*	0.54**	0.46**	0.07*	0.81**						
<b>TLNP</b>	0.38**	0.30*	0.33*	-0.04*	0.09*	0.45**	0.24*	0.10*	0.17**					
<b>TLDWP</b>	-0.21*	0.06*	0.50**	0.16*	0.62**	0.46**	-0.09*	0.73**	0.93*	0.10*				
<b>TLFWP</b>	-0.24*	0.26*	0.59**	0.37**	0.71**	0.69**	-0.11*	0.94**	0.79**	0.04*	0.79**			
<b>TSNP</b>	-0.03*	0.04*	0.43**	-0.06*	0.39**	0.34*	0.04*	0.19*	0.15**	0.52**	0.18*	0.29*		
<b>THLNP</b>	0.01*	0.18*	0.05*	0.29*	0.13*	0.29*	0.04*	0.65**	0.60**	0.16**	0.50**	0.50**	-0.07*	
	<b>MNSL</b>	<b>LAIFH</b>	<b>LAILH</b>	<b>LAFH</b>	<b>LALH</b>	<b>FLY</b>	<b>PHFH</b>	<b>TSFWP</b>	<b>TSDWP</b>	<b>TLNP</b>	<b>TLDWP</b>	<b>TLFWP</b>	<b>TSNP</b>	<b>THLNP</b>

\*= $p=0.05$ , \*\*= $0.01$

**Legend:** MNSL= Mean new shoot length, LAIFH = Leaf index at first harvest, LAILH=Leaf index at last harvest, LAFH=Leaf area at first harvest, LALH =Leaf area last harvest,FLY= Fresh leaf yield (t/ha), PHFH=Plant height at first harvest, TSFWP=Total shoot fresh weight/plant, TSDWP=Total shoot dry weight/plant TLNP =Total leaf number/plant, TLDWP=Total leaf dry weight/ plant, TLFWP=Total leaf fresh weight/plant, TSNP=Total shoot number/plant THLNP=Total harvested leaf number/plant

## 4.5 Pot Experiment

### 4.5.1 Vegetative Growth

### 4.5.2 Plant height at first harvest

There were significant differences in plant height of cultivars, PAFH, and interactions between cultivar and PAFH.

The Bihi cultivar recorded significantly higher plant height than Mogla 1 cultivar. Plant height of the two cultivars progressively increased from 31, 38 and 45 days of PAFH, as did interactions between cultivar and PAFH at first measurement. At 45 days of PAFH interactions with Bihi cultivar produced the tallest plants (Table 24).

**Table 24: Effect of plant age at first harvest of two roselle cultivars on plant height at harvest**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	25.33	17.66	21.50
38	43.72	30.85	37.29
45	61.47	42.23	51.85
Mean	43.51	30.25	

LSD (P=0.05); Cultivar = 2.67, PAFH = 3.28, Cultivar x PAFH = 4.64, \*PAFH = Plant age at first harvest

#### 4.5.3 Mean new shoots length at harvests

Cultivar, PAFH significantly affected mean new shoot length at subsequent harvest. The Bihi cultivar was taller than the Mogla 1 cultivar and 45 days of PAFH produced longer mean shoot length than 31 and 38 days of PAFH. The interactions between Bihi cultivar and 45 days of PAFH produced the longest mean new shoot length at harvests (Table 25).

**Table 25: Effect of plant age at first harvest of two roselle cultivars on mean new shoot length at harvests**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	12.96	11.03	12.0
38	16.91	13.56	15.24
45	18.12	12.95	15.54
Mean	16.00	12.52	

LSD (P=0.05); Cultivar = 1.01, PAFH = 1.23, Cultivar x PAFH = 1.7, \*PAFH = Plant age at first harvest

#### 4.5.4 Mean new stem diameter at harvests

Table 26 shows mean new stem diameter at harvest, with no significant difference in cultivar.

There were significant differences in PAFH, and interactions between cultivar and PAFH. The 45 days of PAFH recorded a wider new stem diameter than both 31, and 38 days of PAFH.

There were no significant differences between 38 and 45 days of PAFH. The interactions between Bihi cultivar and 45 days of PAFH gave a wider new stem diameter than 31 and 38 PAFH.

**Table 26: Effect of plant age at first harvest of two roselle cultivars on mean new stem diameter for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	2.73	2.91	2.82
38	3.04	3.06	3.05
45	3.17	3.01	3.09
Mean	2.98	2.99	

LSD (P=0.05); Cultivar = NS, PAFH = 0.10, Cultivar x PAFH = 0.15, \*PAFH = Plant age at first harvest

#### 4.5.5 Total number of leaves/plant before harvest

Table 27 illustrates total number of leaves/plant before harvest for the period of harvesting. There was significant difference in PAFH, with 38 days of PAFH producing a higher leaves/plant than 31, and 45 days of PAFH. There were no significant differences between 38 and 45 days of PAFH. There were no significant differences between cultivar, and interactions between cultivar and PAFH.

**Table 27: Effect of plant age at first harvest of two roselle cultivars on total leaf number/plant for the harvest period**

PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	505.0	490.0	498.0
38	668.0	661.0	664.0
45	672.0	527.0	600.0
Mean	615.0	559.0	

LSD (P=0.05); Cultivar = NS, PAFH = 83.7, Cultivar x PAFH = NS

#### 4.5.6 Total new shoots/plant

There were no significant differences between total new shoots/plant at cultivar, and interactions between cultivar and PAFH. There was significant difference in PAFH, with 38 days of PAFH producing more total new shoots than 31 and 45 days of PAFH. There was no significant difference between 38 and 45 days of PAFH (Table 28).

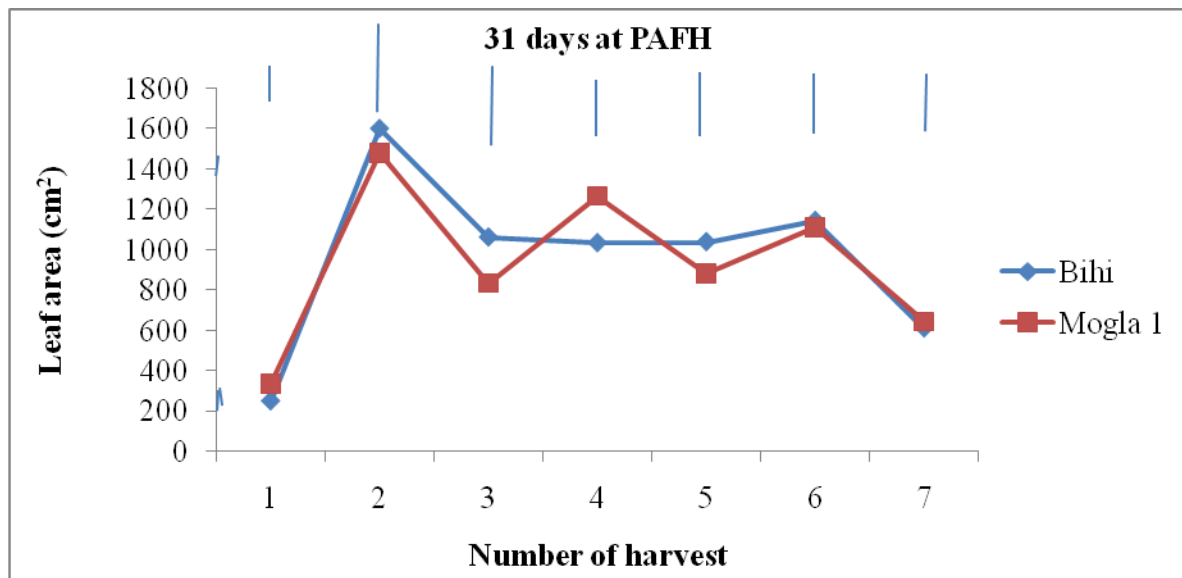
**Table 28: Effect of plant age at first harvest of two roselle cultivars on total new shoot/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	83.0	82.0	83.0
38	95.0	92.0	94.0
45	97.0	88.0	92.0
Mean	92.0	87.0	

LSD (P=0.05); Cultivar = NS, PAFH = 8.47, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.5.7 Leaf area (cm<sup>2</sup>) at harvest

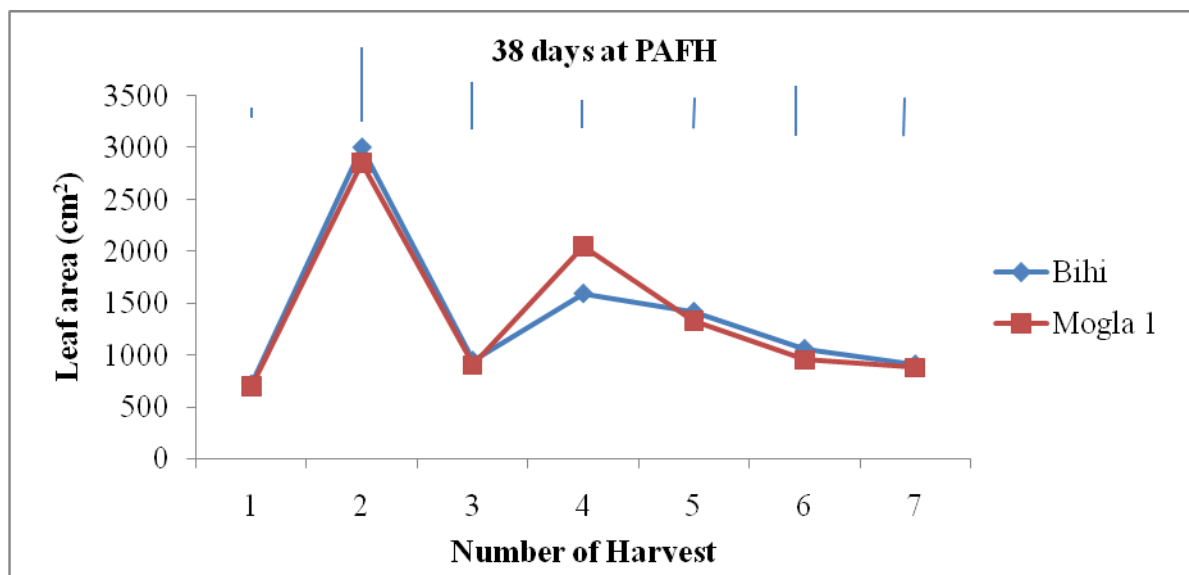
Bihi and Mogla 1 cultivars produced their highest leaf area at second harvest and lowest leaf area at the seventh harvests. At first Bihi cultivar had slightly lower leaf area than Mogla 1 cultivar but with the exception of the fourth harvest. Bihi cultivar constantly showed higher leaf area than Mogla 1 at all harvest (Fig.12).



**Figure 12: Effect of two roselle cultivars and plant age at first harvest on leaf area at harvest**

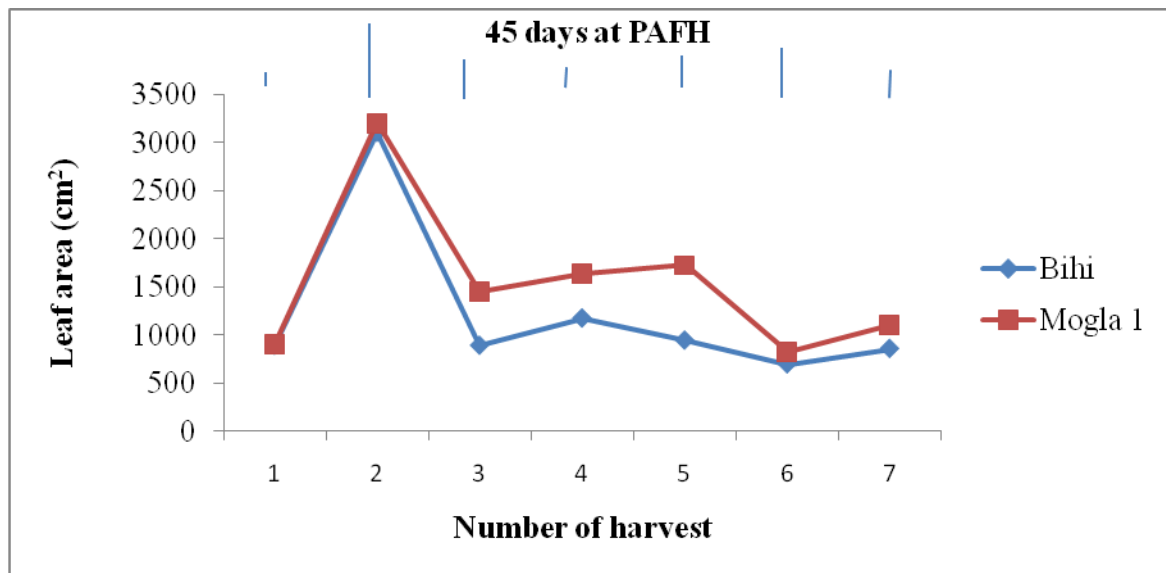
At 38 days of PAFH, Bihi cultivar recorded a higher leaf area/plant compared to Mogla 1 cultivar at first harvest and reached its peak at second harvest and declined sharply from harvest to third harvest. This was followed by slight increase in leaf area/plant at the fourth harvest and gradually decline to the end of the experiment.

The Mogla 1 cultivar produced a higher leaf area/plant at fourth harvests compared to Bihi cultivar followed by progressive decrease in leaf area to the end of the experiment (Fig.13).



**Figure 13: Effect of two roselle cultivars and plant age at first harvest on leaf area at harvest**

The Mogla 1 cultivar produced a higher leaf area/plant at the first harvest compared with Bihi and reached its peak at second harvest and declined sharply from the second harvests to the third harvests and continued with fairly constant increase and declined at har harvest, but increased slightly at the last harvest. The Bihi cultivar showed similar pattern of leaf area development but had consistently lower leaf area than Mogla 1 cultivar throughout the experiment (Fig.14).



**Figure 14: Effect of two roselle cultivars and plant age at first harvest on leaf area at harvest**

## 4.6 Flowering

### 4.6.1 Number of days to flower bud appearance

Table 29 shows number of days to flower bud appearance. There were significant differences in the following ; cultivar, PAFH, and interactions between cultivar and PAFH.

The Bihi cultivar took fewer days for the appearance of flower bud than Mogla 1. The 31 and the 45 PAFH had the same mean days of flower bud appearance.

**Table 15: Effect of two roselle cultivars and plant age at first harvest on number of days to flower bud appearance**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	34.0	43.0	39.0
38	34.0	43.0	38.0
45	34.0	44.0	39.0
Mean	34.0	43.0	

LSD (P=0.05); Cultivar = 0.17, PAFH = 0.21, Cultivar x PAFH = 0.29, \*PAFH=Plant age at first harvest

## 4.7 Yield and Yield Components

The yield mainly consisted of harvested shoots and yield components comprised harvested leaves (leaf blade), petioles, and stems.

### 4.7.1 Total shoot fresh weight/plant

There were no significant differences in shoot fresh weight/plant for cultivar, and interactions between cultivar and PAFH. There was significant difference in total shoot fresh weight in PAFH. The 45 days recorded a greater total fresh shoot weight/plant compared to 31 and 38 days PAFH. There were significant differences between 31 and 38 days PAFH (Table 30).

**Table 16: Effect of two roselle cultivars and plant age at first harvest on total shoots fresh weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	309.00	321.00	315.0
38	416.00	405.00	411.0
45	504.00	386.00	445.00
Mean	410.0	370.0	

LSD (P=0.05); Cultivar = NS, PAFH = 60.7, Cultivar x PAFH = NS \*PAFH = Plant age at first harvest

### 4.7.2 Total shoot dry weight/plant

Cultivar and PAFH significantly affected total shoot dry weight/plant for the harvest period. The Bihi cultivar produced a greater total shoot dry weight/plant than Mogla 1. The 45 days PAFH recorded a higher total shoot dry weight/plant than 31, and 38 days PAFH. There were significant differences between 31 and 38 days PAFH.

Interactions between cultivar and PAFH were not significant (Table 31).

**Table 31: Effect of two roselle cultivars and plant age at first harvest on total dry shoot weight (g)/plant for the harvest period**

□ PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	54.70	54.20	54.50
38	69.40	66.10	67.80
45	92.10	70.50	81.30
Mean	72.10	63.60	

LSD (P=0.05); Cultivar = 7.81, PAFH = 9.57, Cultivar x PAFH = NS , \*PAFH = Plant age at first harvest

#### 4.7.3 Total harvested leaf number/plant

Table 31 shows total harvested leaf number/plant for the harvest time. There were significant differences in the following; cultivar and PAFH. Bihi cultivar produced a higher harvested number of leaves compared to Mogla 1. The 45 days PAFH recorded a higher harvested leaf number/plant than 31 and 38 days of PAFH. There were no significant differences between 31 and 38, and 38 and 45 days PAFH. Interactions between cultivar and PAFH significantly did not affect total harvested leaf number/plant.

**Table 31: Effect of two roselle cultivars and plant age at first harvest on total harvest leaf number/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	327.0	321.0	324.0
38	378.0	337.0	357.0
45	453.0	332.0	393.0
Mean	386.0	330.0	

LSD (P=0.05); Cultivar = 34.96, PAFH = 42.82, Cultivar x PAFH = 60.55, \*PAFH = Plant age at first harvest

#### 4.7.4 Total leaf fresh weight/plant

Cultivar and interactions between cultivar and PAFH did not cause any significant differences in total leaf fresh weigh/plant. PAFH significantly affected total leaf fresh weight/plant. A higher total leaf fresh weight/plant was recorded at PAFH of 45 days than 31, and 38 days. There was no significant difference between PAFH at 38 and 45 days (Table 32).

**Table 32: Effect of two roselle cultivars and plant age at first harvest on total fresh leaf weight (g)/plant for the harvest period**

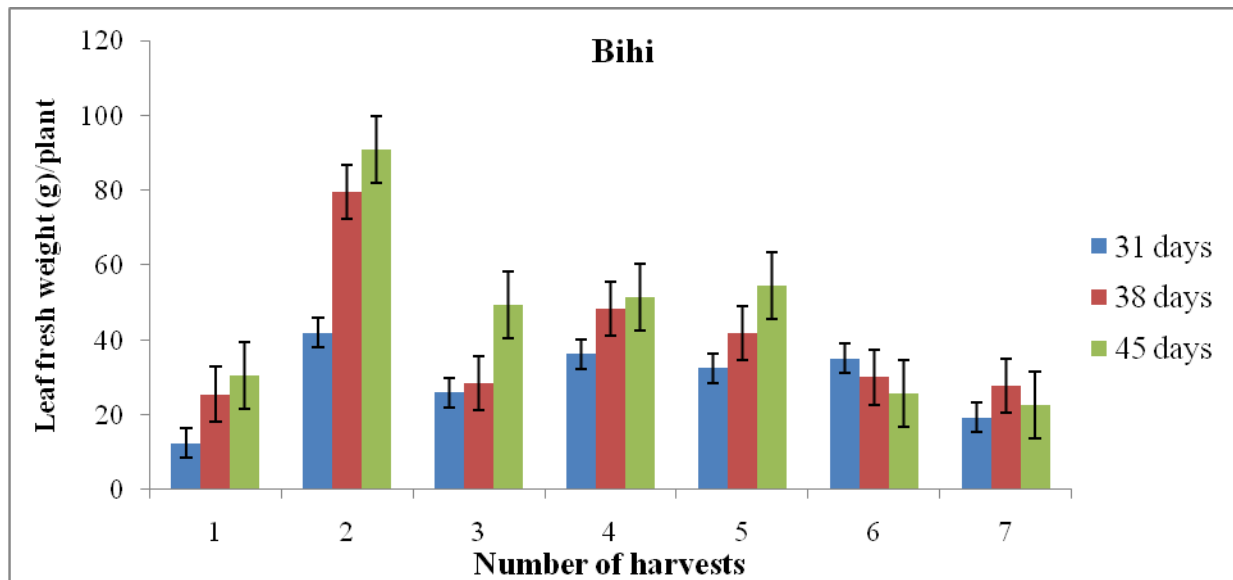
*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	197.80	204.90	197.80
38	258.90	261.90	258.90
45	279.20	249.70	279.20
Mean	251.70	238.80	

LSD (P=0.05); Cultivar = NS, PAFH = 39.16, Cultivar x PAFH = NS, \*PAFH = Plant age at

first harvest

#### 4.7.5 Trend of leaf fresh weight/plant

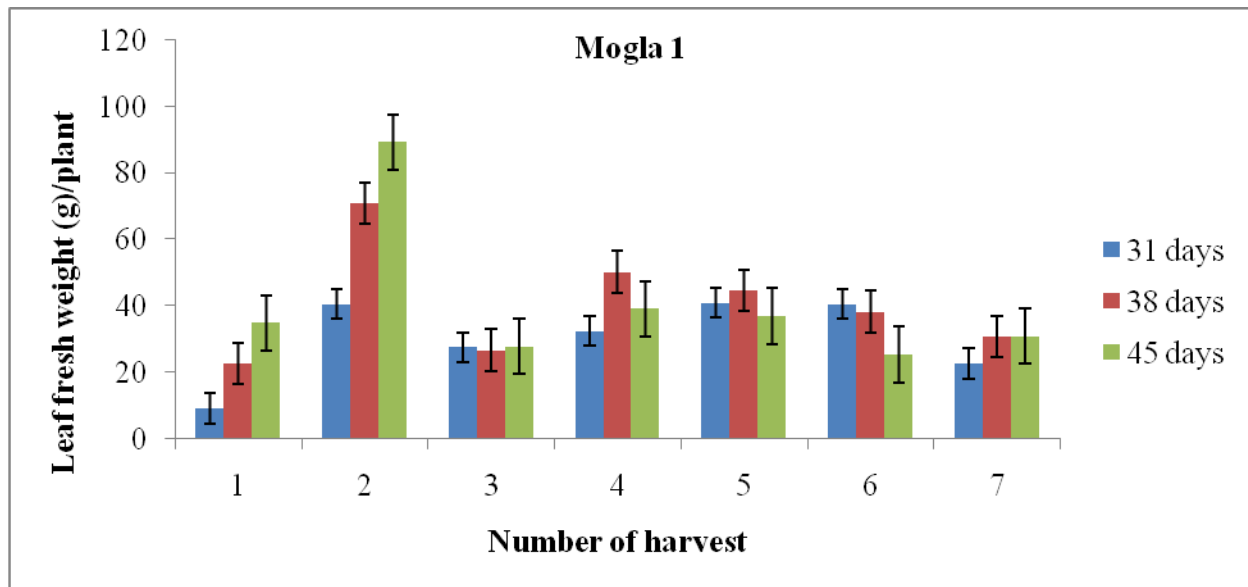
Bihi fresh leaf weight/plant peaked at the second harvest with PAFH of 45 days but declined sharply from second to third harvest and continued to show some increase during the 4<sup>th</sup> and 5<sup>th</sup> harvests followed by a decline in the last two harvests. The 45 days of PAFH recorded a higher leaf fresh weight/plant up to the fifth harvest than at PAFH of 31 and 38 days and decreased at the sixth harvests (Fig.15).



**Figure 15: Effect of two roselle cultivars and plant age at first harvest on fresh leaf weight (g)/plant**

Mogla 1 cultivar peaked at second harvest and sharply decreased from second harvest to third harvest with PAFH of 38 days recording significantly higher fresh leaf weight than 31 and 45 days of PAFH at the fourth harvests in Mogla 1 cultivar. (Fig.16). The 31 days of PAFH recorded a greater leaf fresh weight than 38 and 45 at sixth harvests and the lowest at seventh harvest with

both Bihi and Mogla 1 cultivars.



**Figure 16: Effect of two roselle cultivars and plant age at first harvest on fresh leaf weight (g)/plant**

#### 4.7.6 Total leaf dry weight/plant

Table 33 shows total leaf dry weight/plant for the harvest time. There were no significant differences in cultivar, and interactions between cultivar and PAFH. There was significant difference in total leaf dry weight/plant at PAFH. Higher total leaf dry weight/plant was recorded at PAFH of 45 days than 31 and 38 days. There was no significant difference between PAFH at 38 and 45 days.

**Table 33: Effect of two roselle cultivars and plant age at first harvest on total dry leaf weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	37.30	38.00	37.70
38	46.10	45.70	45.90
45	57.70	46.40	52.00
Mean	47.00	43.40	

LSD (P=0.05); Cultivar = NS, PAFH= 6.40, Cultivar x PAFH = NS , \*PAFH = Plant age at first

#### 4.7.9 Total harvested stem number/plant

There were significant differences in total harvested stem numbers for the harvesting period in the following; cultivar, PAFH, and interactions between cultivar and PAFH. The Bihi cultivar recorded a higher total number of harvested stems/plant than Mogla 1. There was no significant difference at PAFH between 38 and 45 days, but there were significant differences at PAFH between 31, 38 and 45 days. Interactions between Bihi and PAFH at 45 days recorded a higher total harvested number of stems/plant than PAFH 31 and 38 days. There was no significant interaction effect between Bihi and PAFH at 38 and 45 days, and Bihi and Mogla 1 at PAFH at 31 days (Table 34).

**Table 34: Effect of two roselle cultivars and plant age at first harvest on total harvested stem number/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	55.0	54.0	55.0
38	62.0	57.0	59.0
45	66.0	54.0	60.0
Mean	61.0	55.0	

LSD (P=0.05); Cultivar = 2.45, PAFH = 3.00, Cultivar x PAFH = 4.24, \*PAFH = Plant =age at first harvest

#### 4.7. 10 Total stem fresh weight/plant

Table 35 illustrates total stem fresh weight/plant for the harvesting period. Cultivar, PAFH, and interactions between the cultivar and PAFH significantly affected total stem fresh weight/plant. The Bihi cultivar recorded a greater total stem fresh weight/plant than Mogla 1. The 45 days of PAFH recorded a higher total fresh stem weight/plant than 31, and 38 days of PAFH. There were significant differences at PAFH between 31 and 38 days. Interactions between Bihi cultivar and at PAFH of 45 days yielded a greater total stem fresh weight/plant than at PAFH of 31 and 38 days. There were no significant differences between the interactions of Bihi at PAFH of 31 and 38 days and interactions between Mogla 1 at PAFH of 31 and 38 days.

**Table 17: Effect of two roselle cultivars and plant age at first harvest on total stem fresh weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	85.30	74.50	79.90
38	120.00	97.20	108.60
45	148.10	93.10	120.60
Mean	117.80	88.20	

LSD (P=0.05); Cultivar = 14.44, PAFH = 17.68, Cultivar x PAFH = 25.00, \*PAFH = Plant age at first harvest

#### 4.7. 11 Total stem dry weight/plant

Table 36 shows total stem dry weight/plant, where there were significant differences at cultivar, PAFH, and interactions between cultivar and PAFH. Bihi cultivar recorded a higher stem dry weight than Mogla 1 cultivar. The 45 days of PAFH gave a higher total stem dry weight/plant than at PAFH of 31 and 38 days. There were significant differences between 31 and 38 days. Interactions between Bihi cultivar and PAFH of 45 days yielded a greater total stem dry weight/plant than at PAFH of 31 and 38 days. There were no significant differences between the interactions of Bihi at PAFH of 31 and 38 days and interactions between Mogla 1 cultivar at PAFH of 31 and 38 days.

**Table 18: Effect of two roselle cultivars and plant age at first harvest on total dry stem weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	12.79	10.51	11.65
38	17.56	14.09	15.83
45	26.77	17.10	21.94
Mean	19.04	13.90	

LSD (P=0.05); Cultivar = 2.120, PAFH = 2.59, Cultivar x PAFH = 3.67, \*PAFH = Plant age at first harvest

#### 4.8 Flower Bud Yield

##### 4.8.1 Total harvested flower bud number/plant

Cultivar, PAFH, and interactions between cultivar and PAFH significantly affected total harvested flower bud number/plant. Bihi cultivar produced a higher flower buds/plant than Mogla 1.

More flower buds were harvested at 45 days of PAFH than 31 and 38 days. There was no significant difference between 38 and 45 days. Interactions between Bihi and PAFH at 45 days recorded a higher harvested flower buds/plant than 31 and 38 days. There were significant differences between interactions at PAFH of 31 and 38 days with both Bihi and Mogla 1 (Table 37).

**Table 37: Effect of two roselle cultivars and plant age at first harvest on total flower bud number/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	110.0	69.0	89.0
38	181.0	117.0	149.0
45	212.0	115	163.0
Mean	167.0	100.0	

LSD (P=0.05); Cultivar = 14.78, PAFH = 18.10, Cultivar x PAFH = 25.59, \*PAFH = Plant age at first harvest

#### 4.8.2 Total flower bud fresh weight/plant

Table 38 illustrates total fresh flower bud weigh/plant for the harvesting period. There were significant differences at cultivar and PAFH. Bihi cultivar recorded a higher flower bud fresh weight/plant than Mogla 1 cultivar. The 45 days PAFH also recorded a greater flower bud fresh weight/plant than 31 and 38 days of PAFH. There were significant differences between 31 and 38 days of PAFH, but there was no significant difference between 38 and 45 days. There were no significant differences between interactions of cultivar and PAFH.

**Table 19: Effect of two roselle cultivars and plant age at first harvest on total fresh flower bud weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	8.94	5.01	6.97
38	15.62	11.94	13.78
45	17.92	13.55	15.74
Mean	14.16	10.17	

LSD (P=0.05); Cultivar = 3.75, PAFH = 4.59, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.8.3 Total flower bud dry weight/plant

Bihi and the Mogla 1 cultivars, and PAFH caused significant effect in total flower bud dry weight/plant. Bihi cultivar recorded a greater total flower bud dry weight than Mogla 1 cultivar. The 45 days PAFH recorded a greater flower bud dry weight/plant than 31 and 38 days of PAFH. There were significant differences between 31 and 38 days of PAFH, but there was no significant difference between 38 and 45 days. There were no significant differences between interactions of cultivar and PAFH (Table 39).

**Table 20: Effect of two roselle cultivars and plant age at first harvest on total dry flower bud weight (g)/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	1.76	0.98	1.37
38	2.82	1.84	2.33
45	3.44	2.41	2.93
Mean	2.67	1.74	

LSD (P=0.05); Cultivar = 0.64, PAFH = 0.79, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.9. Allometric Ratios

##### 4.9.1 Mean leaf blade/stem Ratio (fresh weight basis)

Table 40 shows mean leaf/stem ratio for the harvest period (fresh weight basis), in which there was significant difference in cultivar. The Mogla 1 cultivar recorded a higher leaf/stem ratio than Bihi cultivar. There were no significant differences in PAFH, and interactions between cultivar and PAFH.

**Table 21: Effect of two roselle cultivars and plant age at first harvest on mean leaf blade/stem ratio (fresh weight basis)**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	2.26	2.96	2.61
38	2.17	2.76	2.46
45	2.17	2.59	2.38
Mean	2.20	2.77	

LSD (P=0.05); Cultivar = 0.19, PAFH = NS, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.9.2 Mean leaf blade/stem ratio (dry weight basis)

Table 41 illustrates mean leaf/stem ratio (dry weight basis) for the harvest time. There were significant differences in cultivar and PAFH. Mogla 1 recorded higher leaf/stem ratio than Bihi cultivar. PAFH of 31 days recorded a greater mean leaf blade/stem ratio than 38 and 45 days. There were significant differences in leaf/stem ratio (dry weight basis) between 38 and 45 days. There were no significant differences between interactions of cultivar and PAFH.

**Table 22: Effect of two roselle cultivars and plant age at first harvest on mean leaf blade/stem ratio (dry weight basis)**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	3.03	3.79	3.41
38	2.73	3.49	3.11
45	2.40	2.9	2.66
Mean	2.72	3.40	

LSD (P=0.05); Cultivar = 0.23, PAFH = 0.28, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.9.5 Mean leaf/shoot ratio (fresh weight basis)

There was significant difference in cultivar, Mogla 1 cultivar produced a higher leaf /shoot ratio on fresh weight basis than Bihi cultivar. However, there were no significant differences in PAFH, and interactions between cultivar and PAFH (Table 42).

**Table 42: Effect of two roselle cultivars and plant age at first harvest on mean leaf/shoot ratio (fresh weight basis)**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	0.72	0.76	0.74
38	0.71	0.75	0.73
45	0.70	0.75	0.73
Mean	0.71	0.76	

LSD (P=0.05); Cultivar = 0.01, PAFH = NS, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.9.6 Mean leaf/shoot ratio (dry weight basis)

There were significant differences in cultivar and PAFH. Mogla 1 cultivar recorded a higher leaf /shoot ratio on dry weight basis than Bihi cultivar. PAFH at 31 days recorded a higher leaf /shoot ratio in terms of dry weight basis than 38 and 45 days. There were significant differences between 38 and 45 days. Interactions between cultivar and PAFH did not caused any significant effect on average leaf/shoot ratio (Table 43)

**Table 43: Effect of two roselle cultivars and plant age at first harvest on mean leaf/shoot ratio (dry weight basis)**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	0.76	0.80	0.78
38	0.74	0.78	0.76
45	0.70	0.75	0.73
Mean	0.74	0.78	

LSD (P=0.05); Cultivar = 0.01, PAFH = 0.01, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### **4.10 Number of unmarketable leaves/plant**

##### **4.10.1 Total number of unmarketable leaves/plant**

There were significant differences in total number of unmarketable leaves/plant for cultivar and PAFH. Bihi cultivar produced a greater number of unmarketable leaves than the Mogla 1. The 45 days PAFH also recorded a higher number of unmarketable leaves/plant than 31 and 38 days of PAFH. There were no significant differences between 31 and 38 days, and interactions between cultivar and PAFH (Table 44).

**Table 23: Effect of two roselle cultivars and plant age at first harvest on total unmarketable leaf number/plant for the harvest period**

*PAFH (days)	Cultivar		Mean
	Bihi	Mogla 1	
31	9.0	6.0	8.0
38	13.0	10.0	12.0
45	23.0	10.0	16.0
Mean	15.0	9.0	

LSD (P=0.05); Cultivar = 4.36, PAFH = 5.34, Cultivar x PAFH = NS, \*PAFH = Plant age at first harvest

#### 4.11 Relationship among some parameters of roselle in the pot experiment

Table 45 shows the relationship among some of the parameters studied using correlation matrix in the pot experiment. Sizable number of the correlation coefficient (r) of parameters measured were significant (p = 0.01) and few were significant (p = 0.05). Stronger association occurred between total leaf fresh weight/plant and total shoot fresh weight (r = 0.98) followed by total leaf dry weight/plant and total shoot dry weight/plant (r = 0.97).

Other parameters with strong association include plant height at first harvest and average new shoot length (r = 0.86), total harvested leaf number per plant and average new shoot length (r = 0.85), total leaf fresh weight per plant and plant height at first harvest (r = 0.81), and total shoot number per plant and total leaf number per plant (r = 0.93).

**Table 24: Correlation matrix (r) among some parameters of roselle in the pot studies**

<b>MNSL</b>											
<b>PHFH</b>	0.86**										
<b>LAFH</b>	0.60**	0.80**									
<b>LALH</b>	0.64**	0.68**	0.53*								
<b>TLNP</b>	0.79**	0.61**	0.55*	0.65**							
<b>THLNP</b>	0.85**	0.83**	0.57*	0.81**	0.72**						
<b>TLDWP</b>	0.77**	0.87**	0.75**	0.84**	0.71**	0.92**					
<b>TLFWP</b>	0.73**	0.81**	0.74**	0.76**	0.71**	0.84**	0.95**				
<b>TSDWP</b>	0.80**	0.92**	0.78**	0.78**	0.67**	0.92**	0.98**	0.93**			
<b>TSFWP</b>	0.81**	0.86**	0.74**	0.78**	0.73**	0.90**	0.97**	0.98**	0.96**		
<b>TSNP</b>	0.785**	0.64**	0.58*	0.70**	0.93**	0.78**	0.75**	0.71**	0.78**	0.75**	
	<b>MNSL</b>	<b>PHFH</b>	<b>LAFH</b>	<b>LALH</b>	<b>TLNP</b>	<b>THLNP</b>	<b>TLDWP</b>	<b>TLFWP</b>	<b>TSDWP</b>	<b>TSFWP</b>	<b>TSNP</b>

\*=p=0.05, \*\*=0.01

**Legend:** ANSL= Mean shoot length, PHFH =Plant height at first harvest, LAFH = Leaf area at first harvest, LAFH = Leaf area last harvest, TLNP = Total leaf number/plant THLNP =Total harvested leaf number/plant, TLDWP = Total leaf dry weight/plant, TLFWP= Total leaf fresh weight/plant, TSDWP=Total shoot dry weight/plant, TSFWP=Total shoot fresh weight/plant, TSNP =Total shoot number/plant

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Vegetative Growth

##### 5.1.1 Plant height at first harvest

###### Interactions

Interactions between cultivar and spacing impacted plant height significantly in the field experiment at first harvest. The Bihi cultivar produced taller plants at 30cm x 30cm spacing than the 30cm x 45cm spacing (Table 2). This might be due to the plants competition for growth promoting factors such as light, space and nutrients. The results are in conformity with Singh and Whitehead (1993) on amaranthus; Ramos *et al.* (2011) on roselle, and Wenyonu *et al.* (2011) on okra which showed that closer spacing produced taller plants than wider spacing. Closely spaced plants might have competed for light for photosynthesis thereby growing taller.

The Bihi cultivar produced significantly taller plants than Mogla 1 and Mogla 2 or Mogla 1 cultivars in field and pot experiments respectively. The differences in plant height could be assigned to differences in the genetic make-up of the roselle cultivars. These results confirmed reports by Schippers (2000) and Grubben and Denton (2004) which indicated that there are differences in roselle cultivars in terms of plant height.

Cultivar x PAFH (plant age at first harvest) interactions also significantly affected plant height at first harvest in the pot experiment. Bihi cultivar produced taller plants at 45 days of PAFH than Mogla 1 cultivar at 31 and 38 days of PAFH, this could have been due to

differences in genetic composition of the cultivars combined with longer age at which initial harvesting was done. The results agreed with Norman and Sichone (1993) and Osei-Kwateng *et al.* (2012) where initial age at harvesting influenced plant height (Table 29).

### **5.1.2 Mean new shoots length at harvest**

#### Interactions

The interactions between the 30cm x 30cm spacing and Bihi in the field experiment produced the longest new shoots followed by the 30cm x 40cm, 30cm x 35cm, 30cm x 45cm spacings (Table 3). This could be attributed to competition for space, nutrients, sunlight, and moisture, where in the dense plant population, plants compete for space causing the stems to elongate to expose the plants to sunlight for photosynthetic activities. These findings confirmed the results of Muoneke and Asiegbu (1997), Talukder *et al.* (2003), and Wenyonu *et al.* (2011) on okra where higher plant population density promoted stem elongation leading to taller plants.

The longest mean new shoots length was produced by the Bihi cultivar followed by the Mogla 1 and Mogla 2 cultivars in the field and pot experiments. There was 57.0%, 55.9% and 56.8% reduction of new shoots length at second and last stages of harvest of Bihi, Mogla 1 and Mogla 2 cultivars respectively in the field experiment. In the pot experiment, Bihi cultivar had 70.2% reduction in new shoots length while Mogla 1 cultivar new shoots length reduced by 50.3%. This observation is confirmed by studies on okra by Wenyonu *et al.* (2011) who reported a decrease in plant height with subsequent

pruning of two okra varieties. The differences in plant height of the three cultivars could also be attributed to differences in their genetic make-up of the roselle cultivars.

There was positive correlation ( $r = 0.83^{**}$ ) and ( $r = 0.16^{**}$ ) between plant height at first harvest and total harvested leaf number/plant for pot and field experiment respectively. Plant height at first harvest had a positive impact on the amount of leaves that could be harvested. Since the harvest is to be done at a particular height. The Bihi cultivar recorded more total harvested leaves/plant than the Mogla 1 cultivar in the pot experiment since it was taller than Mogla 1 cultivar.

### **5.1.3 Leaf number/plant**

#### Interactions

Cultivar x spacing interactions had a significant effect on total leaf number observed in the field experiment. The Mogla 1 at 30cm x 30cm spacing produced higher number of leaves compared to Bihi and Mogla 2 cultivars and the wider spacing 30cm x 45cm (Table 5). This could be explained, according to (Janick, 1979 and Norman, 1992) that high population density does not affect the individual plant's performance once the plant density is below the level at which competition occurs between plants. Correlation studies showed a positive association between total leaf number/plant and total shoot number/plant ( $r = 0.52^{**}$ ) and ( $r = 0.93^{**}$ ) in the field and pot studies respectively. This is in agreement with Edmond *et al.* (1977); Janick (1979); Dun *et al.* (2006); Schimizu-Sato *et al.* (2009) that, apical dominance is broken when the apical bud is removed, promoting lateral buds growth resulting in production of more shoots and leaves. Leaf numbers increased to the peak at second harvest after stopping of the plants at 31 DAS

and declined from second to third harvest and slowly increased at fourth harvest in the field experiment. The results are also confirmed by (Olufolaji and Tayo, 1989; Norman, 1994; Kutor, 2008; Fu, 2008; Oti, 2009 and Wenyonu *et al.*, 2011) who indicated that pruning caused plant branching, leading to an increase in leaf number.

There was no significant difference in total leaf number/plant for cultivars in both field and pot experiments.

#### Plant age at first harvest (PAFH)

There were significant differences in leaf production relating to PAFH, with 38 days of PAFH producing more leaves than the 31 and 45 days of PAFH. This could be attributed to initial age at which harvesting started. The 45 days of PAFH had fewer leaves due to leaf senescence and dropping of old leaves. The findings buttress the results of Mnzava and Massam (1985) and Norman (1994) who suggested that harvesting of leafy crops should coincide with their active stage of growth. Although, there was no significant difference in total leaf number between the Bihi and the Mogla 1 cultivars, the Bihi cultivar produced more leaves than the Mogla 1. With adequate watering in the pot experiment, the Bihi cultivar's performance was enhanced.

#### 5.1.4 New shoots number/plant

##### Interactions

There were significant differences between total new shoots number for the interactions between cultivar x spacing. The Mogla 1 produced more new shoots at 30cm x 30cm spacing than Bihi and Mogla 2 cultivars, and the 30cm x 35cm, 30cm x 40cm, and 30cm x 45cm spacings with plant densities of 222,222/ha, 190,476/ha, 166,667/ha, and 148,148/ha respectively (Table 6).

This could be explained, by the assertion of Janick(1979); Norman(1992); and El Naim *et al.* (2012) that high population density does not affect the individual plant's functioning, once the plant density is below the level at which competition occurs between plants.

However, studies by Norman and Shongwe (1993) and Norman (1994) revealed that wider spacing of *Amaranthus hybridus* L. significantly produced more shoots per plant than closer spacing, because the plants had access to more space, nutrients and other growth promoting factors than the closer spacing. Furthermore, harvesting by cutting or pruning breaks apical dominance leading to production of more shoots as reported by (Edmond *et al.*, 1977; Janick (1979); Norman (1994); Dun *et al.*, 2006; and Schimizu-Sato *et al.*, 2009). As more shoots are produced photosynthesis will also be enhanced boosting vegetative growth.

There was positive association ( $r = 0.93^{**}$ ) and ( $r = 0.52^{**}$ ) between total shoot number/plant and total field leaf number/plant in the pot and field experiments respectively. This is in conformity with (Edmond *et al.*, 1977; Janick (1979); Norman, 2004; Dun *et al.* (2006); Schimizu-Sato *et al.* (2009) that, apical dominance is

broken when the apical bud is removed, promoting lateral buds growth resulting in production of more shoots giving the plant a bushy shape. Also harvesting of Water leaf, *Talinum triangulare* (Jacq.) by cutting facilitated the development of new lateral shoots (Norman, 1992; and Schippers, 2000).

The Mogla 1 cultivar produced significantly more new shoots than Bihi and Mogla 2 cultivars in the field experiment. This could be due to upper hand genetic superiority that the Mogla 1 cultivar might have over the Bihi and Mogla 1 cultivars. Again, the Mogla 1 seems to withstand moisture stress better than the rest of the cultivars when watering was inadequate due to lack of rains and broke down of water pumping machine at the University of Ghana farm during the time of the experiment. In the pot experiment, although there was no significant difference in number of new shoots, the Bihi cultivar produced more new shoots than the Mogla 1 cultivar when there was adequate watering of plants.

#### Plant age at first harvest

There was significant difference in new shoots number in PAFH, with the 38 days of PAFH producing more new shoots than the 31 and 45 days of PAFH but with insignificant difference between 38 and 45 days PAFH (Table 33). Norman and Shongwe (1993) on amaranthus studies indicated that pruning at 2 WAP resulted in the production of more shoots than initial topping at 5 WAP. As leafy vegetable, plants should not unduly stay long in the field before harvesting, optimum age at first harvest is very crucial. Norman (1992) suggested that harvesting of vegetables should be done at the right time.

### 5.1.5 Leaf area/plant

#### Cultivar

There was significant difference in leaf area between the Bihi, Mogla 1 and Mogla 2 cultivars in experiment I. The genetic differences in the cultivars could be attributed to the Bihi cultivar having a higher leaf area/plant than the Mogla 1 and Mogla 2 cultivars at the 31 and 45 DAP. Generally, the leaf area showed a rise and decline in both field and pot experiments (Fig.1 and fig.12) respectively. Akorada and Olufolaji (1981) reported that leaves of *Corchorus olitorius* decreased in size and weight after each harvest. Also, Fu (2008) stated that harvesting caused plant branching, leading to an increase in leaf number and decrease in leaf size.

There were positive association ( $r = 0.81^{**}$ ) and ( $r = 0.13^{*}$ ) between leaf area at last harvest and total harvested leaf number/plant in the pot and field experiments respectively. There was also positive and significant correlation between total leaf fresh weight/plant and leaf area at last harvest ( $r = 0.71^{**}$ ) in the field and leaf area at last harvest in the pot experiment ( $r = 0.76^{**}$ ). This is in agreement with Adeniji and Aremu (2007) where they reported that a sufficient positive correlation between these parameters indicated an effective utilization of photosynthates manufactured in the leaves for growth and development.

#### Plant age at first harvest

The 45 days of PAFH produced higher leaf area/plant than the 31 and the 38 days except at sixth harvest (fig.14) in the pot experiment. This could be due to initial age at which harvesting started. When plants stayed longer after emergence, with available plant

growth and development factors photosynthetic activity is enhanced leading to the production of more leaves/plant and development of larger leaf area/plant at the 45 days of PAFH. The results collaborate with the findings of Adeniji and Aremu (2007) and Norman (1994) where increase in size coincided with initial age of first harvest.

### **5.1.6 Leaf area index (LAI)**

#### Cultivar

The Mogla 2 cultivar had the least LAI as compared to the Bihi and Mogla 1 cultivars in the field experiment. This could be due to varietal differences in terms of their genetic composition. Akoroda and Olufajo (1981) reported that leaves of *Corchorus olitorius* decreased in size and weight after each harvest. There was positive association ( $r = 0.92^{**}$ ) between the leaf area at last harvest and leaf area index at last harvest in the field experiment. The Mogla 1 cultivar had a higher LAI at the last harvest than Bihi and Mogla 2 cultivars. This could also be due to differences in genetic make-up. The observation confirms Grubben (1977) and Grubben and Denton (2004) reports of cultivar differences among roselle plants.

#### Spacing

The 30c x 30cm produced a significantly higher LAI throughout all the stages of harvest than the 30cm x 35cm, 30 x 40cm, and 30cm x 45cm spacings. There was a positive correlation ( $r = 0.50^{**}$ ) between leaf area index at last harvest and total leaf dry

weight/plant in the field experiment. These results agreed with that of Wenyonu *et al.* (2011) on okra where they reported that close spacing produced plants with higher LAI than wider spacing. The LAI of a crop at a specific stage of plant growth and development shows the photosynthetic ability and its dry matter accumulation.

Rasheed *et al.* (2003) stated that the higher the LAI, the higher the dry matter accumulation potential of the crop and vice versa. Wider spacing provided plants with larger land area as compared to close spacing and this in turn increased the LAI of plants in the close spacing. Hence, the results are in conformity with that of Muoneke and Asiegbu (1997); Muoneke and Mbah (2007); and Muoneke *et al.* (2002) who indicated that LAI increased with increase in plant density.

### **5.3 Yield and Yield Components**

#### **5.3.1 Shoot fresh and dry weights per plant and shoot fresh yield**

##### Cultivar

The Mogla 1 cultivar's total and shoot fresh and dry weight (g)/plant and shoot fresh yield t/ha significantly outyielded those of Bihi and Mogla 2 cultivars with insignificant difference in shoot fresh yield t/ha between Bihi and Mogla 2 cultivars in the field experiment. Bihi cultivar shoot dry weight/plant was higher than Mogla 1 cultivar in the pot experiment. Genetic superiority and adaptability to moisture stress conditions by Mogla 1 cultivar might have contributed to its better performance than the other two cultivars. These findings are in agreement with Grubben (1977), Norman (1992),

Schippers (2000) and Grubben and Denton (2004) who reported the existence of different roselle cultivars with different growth and performance potentials.

#### Plant age at first harvest

PAFH significantly affected total shoot fresh and dry weight (g)/plant in the pot experiment. The 45 days of PAFH recorded a higher total shoot fresh and dry weight/plant than 31 and 38 days of PAFH.

With initial harvesting at 45 days, more dry matter accumulated in the plants making the plants bigger which reflected in the higher total fresh and dry weights at 45 days than 31 and 38 days. This observation confirms the findings of Mnzava and Massam (1985) and Norman (1994) who suggested that the importance of plant vigour at first harvest cannot be underestimated, and that latter dates of initial harvest yielded higher shoot fresh and dry weight/plant than early dates of initial harvest.

### **5.3.2 Fresh shoot yield (t/ha)**

#### Spacing

In the field studies, the 30cm x 30cm spacing with a higher plant density recorded higher fresh shoot yield of 11.08 t/ha compared to 30cm x 45cm spacings with the least plant density and fresh shoot yield of 7.96 t/ha. Individual plants in wider spacing yielded more than those plants in closer spacing, because the plants have more space and more nutrients, however, the total yields per hectare was greater with closer spacing. The results confirmed the findings of Krishnamurthy *et al.* (1994) on roselle; Norman (1994) on Black jack, and Ramos *et al.* (2011) on roselle, which showed that closer spacing recorded a higher fresh shoot yields than wider spacing.

### 5.3.3 Harvested leaf numbers/plant

#### Cultivar

There were no significant differences in total harvested leaf numbers/plant for cultivar, spacing and interactions between the cultivar and spacing in the field experiment. However, in the pot experiment, Bihi cultivar yielded more harvested leaves numbers/plant than Mogla 1 cultivars. This could be attributed to adequate watering when the water pumping machine on the farm was restored and perhaps differences in genetic make-up between the cultivars. There was significant and positive correlation ( $r = 0.78^{**}$ ) between total harvested leaf numbers and total shoot number per plant in the pot experiment (Table 56). More shoots and leaves were formed as a result of breaking of apical dominance leading to harvesting of higher number of leaves.

There were also positive relationships ( $r = 0.85^{**}$ ); ( $r = 0.0.72^{**}$ ), and ( $r = 0.0.1^*$ ) and ( $r = 0.16^{**}$ ) between total harvested leaf numbers per plant and average new shoot length and total leaf number per plant in the pot experiment and field experiments respectively. These results indicated that more leaves will be harvested the longer the new shoots length and the higher the number of leaves per plant prior to harvesting of the leaves. The results again corroborated the findings of Adeniji and Aremu (2007) that a significant and positive correlation between these parameters indicated an effective utilization of photosynthates manufactured in the leaves.

The Bihi cultivar had 15 total unmarketable harvested leaves/plant in the pot experiment, out of which 9 were due to senescence and 6 were due to more than 50% punctured with holes by insect infestations or other mechanical damage. There was more reduction in

leaves in the Mogla 1 cultivar than the Bihi cultivar as a result of the appearance of flower buds in the pot experiment. Again, the Bihi cultivar significantly produced more number of total flower buds harvested than the Mogla 1 cultivar. These findings are in agreement with Mansour (1975) who revealed that temperature and photoperiod caused the development of lateral buds into flowers and the reduction of the number of branches produced.

#### Plant age at first harvest

Even though 45 days of PAFH gave more harvested leaves than 31, and 38 days of PAFH, there were no significant differences between 31 and 38, and 45 days and 38 days. The longer the plant stayed on the field before the initial harvest the more the likelihood that the plant will yield more leaves than those harvested earlier. This demonstrates that initial plant height at harvesting and cutting height are very important factors in determining harvested leaf numbers/plant as far as harvesting of roselle by pruning is concerned.

However, when plants stayed unusually longer in the field old leaves senesced and dropped off. The 45 days of PAFH recorded more number of unmarketable leaves than the 31 and 38 days of PAFH. The results are in disagreement with Norman and Shongwe (1993) and Norman (1994) who demonstrated that early harvested plants produced more number of harvested leaves per plant than harvesting later dates.

### 5.3.4 Leaf fresh weight per plant and fresh leaf yield

#### Cultivar

Mogla 1 cultivar recorded a higher (70.10g/plant) total leaf fresh weight/plant and 6.34t/ha fresh leaf yield compared to 57.70g/plant, 5.23t/ha and 58.50g/plant, and 5.29t/ha of Bihi and Mogla 2 cultivars respectively. There were no significant differences in fresh leaf yield between Bihi and Mogla 2 cultivars in the field experiment.

In the pot experiment there were no significant differences in total leaf fresh weight/plant between Bihi and Mogla 1 cultivars, nevertheless the Bihi cultivar recorded 251.70g/plant as compared to 238.80g/plant in the Mogla 1 cultivar. Differences in genetic composition might have contributed to the differences in leaf fresh weight/plant and in t/ha between the cultivars. These results agree with Grubben (1977); Norman (1992); Schippers (2000); and Grubben and Denton (2004) where they indicated that there are several roselle cultivars both domesticated and wild types.

There were positive and significant correlation ( $r = 0.71^{**}$ ) and ( $r = 0.04^{**}$ ) between total leaf numbers per plant and total leaf fresh weight per plant in the pot and field experiment respectively. Correlation between total leaf fresh weight per plant and total harvested leaf number per plant and total leaf fresh weight were also positive and significant in both field and pot experiments. Indicating that an increase in one factor has a positive bearing on the other. These results are in agreement with Adeniji and Aremu (2007) where they indicated that a sufficient positive correlation between the parameter demonstrated an effective utilization of photosynthates manufactured in the leaves for growth and development.

### Spacing

There were no significant differences in total leaf fresh weight/plant in interactions between cultivar and spacing in the field experiment. The 30 x 30 spacing with higher plant population 222,222 plants/ha recorded a higher leaf fresh yield, 6.58 t/ha compared to the 30 x 35, 30 x 40, and 30 x 45 cm spacings with plant population 190, 476 plants/ha, 166,667 plants/ha, and 148,148 plants/ha with corresponding yields of 6.01 t/ha, 5.11 t/ha, and 4.80 t/ha respectively (Table 12).

The results are in agreement with Krishnamurthy *et al.* (1994) where they reported that biomass yield of mesta (*Hibiscus sabdariffa*) decrease with increase in spacing. Obodai (2007) and Ramos *et al.* (2011) on roselle, and Norman and Shongwe (1993); Singh and Whitehead (1993); Mortley *et al.* (1992) on amaranthus; Norman and Shongwe (1991) and Madakadze *et al.* (2007) on Corchorus, and Norman (1994) on Black jack demonstrated that closer spacing produced higher fresh leaf yield than larger spacing.

There were positive and significant relationships ( $r = 0.45^{**}$ ) and ( $r = 0.69^{**}$ ) between total leaf number per plant and total leaf fresh weight per plant and leaf fresh yield respectively. This shows that the number of leaves per plant contributes positively to fresh leaf yield. Since high accumulation of photosynthates will lead to high fresh leaf weight per plant leading to increase in fresh leaf yield.

### Plant age at first harvest

There were no significant differences in total leaf fresh weight/plant between 45 and 38 days. PAFH of 45 days recorded higher (279.20 g/plant) leaf fresh weight /plant as compared to 31 and 38 days of PAFH with 197.80g/plant and 258.90g/plant leaf fresh

weights/plant respectively. This illustrated that adequate dry matter was accumulated at 45 days of PAFH than at 31 and 38 days of PAFH. Determination of optimum age for first harvesting of leafy vegetable is therefore, very important. These findings are in conformity with Mnzava and Massam (1985) and Norman (1994) who showed that latter stages of initial harvest recorded higher leaf fresh weight/plant than early initial stage of harvest.

#### **5.3.4 Harvesting trend of leaf fresh weight/plant**

Leaf fresh weight/plant peaked at second harvests and declined throughout the experiment in both field and pot experiments. There were some shoots reserves after the first harvest and more leaves were harvested at the second harvests. These reflected in the second harvests having a higher fresh leaf weight/plant than the rest of the harvests. The results agreed with Akoroda and Olufajo (1981) who demonstrated that leaves of *Corchorus olitorius* decreased in size and weight after each harvest, and also with Maruo *et al.* (2003) and Takataki *et al.* (2003) who suggested that the amount of residual portion left after cutting affect the regrowth of succeeding leaves.

#### **5.3.5 Leaf dry weight per plant and dry leaf yield**

##### Cultivar

There were no significant differences in dry leaf weight/plant and t/ha between Bihi and Mogla 2 cultivars. The Mogla 1 recorded greater total leaf dry weight/plant 10.63 g/plant and 0.96t/ha than Bihi, 9.03 g/plant, 0.82t/ha and Mogla 2, 9.08 g/plant, 0.81t/h respectively in the field experiment. Genetic superiority and adaptability to low moisture

conditions in the Mogla 1 cultivar might have contributed to its higher dry yield than the two cultivars. Also watering was not adequate in the field experiment due to break down of water pumping machine and lack of rains during the period of the experiment. The results are in agreement with Grubben (1977); Schippers (2000); Grubben and Denton (2004) where they indicated that roselle with reddish stems can withstand more drought conditions than the green-stem roselle types of plants.

Correlation analysis indicated a positive and significant relationship ( $r = 0.0.71^{**}$ ) between total leaf dry weight per plant and total leaf number per plant in the pot experiment. There were also positive and significant relationships between total leaf dry weight per plant and total harvested leaf number per plant, and total dry weight per plant and fresh leaf yield in the field experiment (Table 28).

#### Plant age at first harvest

Although there were no significant differences between 38 and 45 days of PAFH, the 45 days of PAFH recorded a higher total dry leaf weight (52.00g/plant), than 31,(37.70g/plant), and 38 ,(45.90g/plant),and 45,(52.00g/plant) days of PAFH. When initial harvesting of plants coincides with the active growing period of plants greater accumulation of dry matter could be obtained from plants with larger plant size at first age of harvest than the early age of harvest. These results are in conformity with Enyi (1965) and Norman (1994).

#### Spacing

In the field studies, the 30 x 30 cm spacing with the highest plant density recorded a higher leaf total dry yield 1.02 t/ha compared to 30 x 45 cm spacing with the least plant

density of 0.72 t/ha leaf dry weight. Individual plants in wider spacing yielded more than those plants in closer spacing, because the plants had more space and more nutrients, however, the leaf dry yield per hectare was greater with closer spacing.

The results are contrarily to Babatunde *et al.* (2002) and Odeleye *et al.*(2005) who indicated that lower plant population density produced and partitioned higher dry matter to vegetative and reproductive parts due to the availability of more growth promoting factors such as space, nutrients and moisture.

However, the results are in agreement with Ramos *et al.* (2011) on roselle; Norman and Shongwe (1993); Norman (1994) on Black jack; Singh and Whitehead (1993); Mortley *et al.* (1992) on amaranthus; Norman and Shongwe (1991) and Madakadze *et al.* (2007) on Corchorus, indicated that closer spacing produced higher dry leaf yield per hectare than the wider spacing.

### **5.3.6 Harvested stem numbers/plant**

#### Interactions

There were no significant differences in total harvested stem numbers in cultivar, spacing, and interactions between cultivar and spacing in the field experiment.

The cultivar x PAFH interactions produced significant differences in total harvested stem number in the pot experiment, with higher number (66 stems/plants) recorded in Bihi cultivar at 45 days of PAFH than 31 days . There were no significant differences between Bihi cultivar and PAFH at 38 and 45 days, and Bihi and Mogla 1 cultivars with

PAFH of 31 days. The results were not consistent. The least stem numbers (54 stems/plant) was recorded at PAFH of 31 and 45 days in Mogla 1 cultivar.

Although more new shoots were produced at 38 days than 31 and 45 days, when it came to harvesting, the 45 days had larger and more new shoots appropriate for harvesting than the 38 days.

The combined effects of differences in genetic potential of the Bihi cultivar under good watering regime with larger plant size at initial harvest might have contributed to the better performance with the interactions at 45 days compared with the interactions of Mogla 1 at 31 and 38 days. Again, fewer stems were observed with Mogla 1 cultivar than Bihi cultivar as a result of the appearance of flower buds that occurred during the period of the pot experiment which more adversely affected Mogla 1 cultivar than Bihi cultivar. The results are in agreement with Schippers (2000) and Grubben and Denton who reported differences in roselle cultivars. However, the results are contrarily to Norman (1994) who demonstrated that early initial age of harvesting produced more harvested shoots/plant than later initial age of first harvest.

### **5.3.7 Stem fresh and dry weight per plant and fresh stem yield**

#### Spacing

The 30cm x 30cm spacing with higher plant population density recorded significantly higher fresh stem yield t/ha. Various research works conducted on leafy vegetables indicated that closer spacing yielded more than wider spacing. Eventhough individual plants perform better in wider spacing with lower plant population density due to the

availability of more space, nutrients and other plant growth promoting factors than closer spacing, Overall performance on yield t/ha is the reverse.

The results agreed with Norman and Shongwe (1991); Singh and Whitehead (1993); Singh and Whitehead (1993); Norman (1994); Krishnamurthy, *et al.* (1994); Ramos *et al.* (2011) ; and Mortley *et al.* (1992) who indicated that closer spacing yields more than wider spacing. The results are however contrarily to Babatunde *et al.* (2002) and Odeleye *et al.* (2005) who suggested that stem dry weight reduces with increase in plant population

### Interactions

There were no significant differences in stem fresh and dry weight/plant with cultivar interactions with spacing in the field experiment.

In the pot experiment, Bihi cultivar recorded a higher stem fresh and dry weight/plant in the 45 days PAFH than 31 and 38 days. There were no significant differences between the interactions of Bihi with PAFH of 31 and 38 days and interactions between Mogla 1 with PAFH of 31 and 38 days.

The combined effects of genetic potential of Bihi under improvement in the moisture status of the soil in the pot and initial harvesting at 45 days of PAFH perhaps coincided with the active growth of the Bihi cultivar hence, the higher stem weights. These result are in agreement with Enzi (1965) and Mnzava and Massam (1985) where they emphasized the importance of plant vigour at first harvest. Bihi cultivar was less affected in the number of new stems produced than the Mogla 1 as a result of the appearance of the flower buds in the pot experiment.

## **5.4 Number of harvested flower buds per plant**

### Interactions

Bihi cultivar produced significantly higher harvested flower buds at PAFH of 45 days than 31 and 38 days. Bihi cultivar produced greater harvested flower buds/plant than Mogla 1 cultivar. There were significant differences between the interactions of PAFH at 31 and 38 days with both Bihi and Mogla 1 cultivars.

The genetic ability of Bihi cultivar coupled with the initial age at first harvest at 45 days contributed to the higher number of harvested flower buds over the Mogla 1 cultivar. Plants had vigorous growth at 45 days and more flower buds were developed at the 45 days than the 31 and 38 days. Moreover, the Bihi cultivar grows taller than the Mogla 1 cultivar. This observation confirms the findings of Schippers (2000) and Grubben and Denton (2004) who reported genetic differences between roselle cultivars, and that of Mnzava and Massam (1985) who emphasized the effect of initial age at harvest of plants.

## **5.4. Flower bud fresh and dry weight/plant**

### Cultivar

Bihi cultivar produced significantly higher fresh and dry weight/plant than Mogla 1 cultivar in the pot experiment. The total flower bud fresh and dry weight/plant formed 17.84% and 5.0% respectively of the total fresh and dry leaf weight/plant of the Bihi cultivar while that of Mogla 1 cultivar's total flower bud fresh and dry weight/plant formed 15.96% and 3.59% respectively of the total fresh and dry leaf weights/plant.

The higher genetic ability of Bihi cultivar over Mogla 1 cultivar could account for the higher flower bud fresh and dry weight/plant. The observation agreed with Grubben (1977); Norman (1992); Schippers (2000) and Grubben and Denton (2004) who asserted that there are different cultivars of roselle in existence.

#### Plant age at first harvest

PAFH of 45 days recorded greater fresh and dry weight/plant than 31 and 38 days with insignificant differences between 45 and 38 days. Plants were larger at the initial age of first harvest of 45 days probably because more photosynthates were accumulated in the plants than at 31 and 38 days. The findings are in agreement with the research of Enzi (1965); Mnzava and Massam (1985) and Norman (1994) where there was high accumulation of dry matter at later initial age of first harvest than early time of initial harvest.

### **5.5 Mean fresh and dry leaf blade/stem ratios**

#### Cultivar

Mogla 1 cultivar produced significantly higher mean fresh and dry leaf blade/ratios than Bihi and Mogla 2 cultivars in the field and pot experiments with insignificant differences between Mogla1 and Mogla 2 cultivars on both fresh and dry weight basis in the field experiment. Mogla 1 cultivar yielded higher leaf blade/stem ratio on both fresh and dry weight basis than Bihi cultivar in the pot experiment.

The differences in individual plant's genetic constitution might have contributed to the outcome observed. The observation agreed with reports by Norman (1992); Schippers (2000) and Grubben and Denton (2004) regarding genetic differences among roselle cultivars.

#### Plant age at first harvest

PAFH significantly affected mean dry leaf blade/stem ratio in the pot experiment. PAFH of 31 days produced significantly higher mean dry leaf/stem ratio than 38 and 45 days. Plants at 31 days PAFH were more leafy and less stemmy on dry weight basis than those of 38 and 45 days of PAFH. The observation agreed with the findings of Norman and Shongwe (1993) on amaranthus, and Norman (1994) on Black jack, where they showed that plants topped earlier produced significantly higher fresh and dry leaf/stem ratios than those plants topped later.

### **5.3 Mean leaf/shoot ratio (fresh and dry weight basis)**

#### Interactions

Interactions between cultivar and PAFH were not significant in both fresh and dry weight basis in the pot experiment. Again, interactions between cultivar and spacing on fresh weight basis were not significant in the field experiment.

The results of the spacing effects on leaf/shoot ratios (table 27) on dry weight basis were not consistent. Mogla 1 cultivar grown on 30cm x 35cm spacing produced significantly

greater mean leaf/shoot ratio (dry weight basis) followed by 30cm x 40cm spacing. The interactions between Bihi cultivar and 30cm x 45cm, and Mogla 2 cultivar and 30cm x 30cm spacings produced the least mean leaf/shoot ratios. The 30cm x 35cm spacing showed more leafiness than the rest of the spacings in terms of dry weight.

However, all the spacings produced acceptably high ratios. In the pot experiment, Mogla 1 cultivar produced significantly higher leaf/shoot ratios in terms of both fresh and dry weight than Bihi cultivar. The high genetic potential of Mogla 1 cultivar might have caused its better performance than Bihi and Mogla 2 cultivars.

The findings agreed with Schippers (2000) and Grubben and Denton (2004) reported performance differences among roselle cultivars, and Norman (1994) findings on black jack demonstrated that there were insignificant differences in leaf/shoot ratios among four spacings, but the wider spacing recorded higher leaf/shoot ratio than the closer spacing on fresh weight basis.

## CHAPTER SIX

### 6.0 CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 CONCLUSIONS

On the basis of the results of the field and pot experiments, the following conclusions can be drawn for Bihi, Mogla 1, and Mogla 2 cultivars;

- The Bihi cultivar produced the tallest plants with 30cm x 30cm spacing at first harvest in the field experiment. The Bihi was taller than the Mogla 1 at 45 days of PAFH in the pot experiment at first harvest.
- The Bihi cultivar also gave a longer mean new shoot length at harvest than Mogla 1 and Mogla 2 cultivars in both field and pot experiments.
- The 45 days of PAFH produced longer mean new shoots length than 31, and 38 days of PAFH.
- Fortnightly harvesting of the three roselle cultivars by pruning reduced new shoot length.
- The 30cm x 30cm spacing produced more total leaves followed by the 30cm x 35cm spacing with insignificant differences in leaf numbers between Bihi, Mogla 1 and Mogla 2 cultivars in the field experiment.
- The 30cm x 30cm spacing produced more new shoots and leaves than 30cm x 35cm, and 30cm x 45cm spacings in the field experiment.

- The 38 days of PAFH yielded more new shoots and total leaf numbers than 31 and 45 days of PAFH with insignificant differences between 38 and 45 days of PAFH in both new shoots and total leaf numbers.
- Eventhough there were insignificant differences in harvested stem and leaf numbers between 38 and 45 days PAFH, the 45 days had higher harvested stem and leaf numbers than the 38 days.
- The 45 days of PAFH had more ageing leaves than 31, and 38 days of PAFH.
- The Bihi cultivar yielded higher leaf area/plant at first harvest than Mogla 1 and Mogla 2 and peaked at the second harvest and declined throughout the field experiment. The Mogla 1 produced more leaf area/plant than Bihi and Mogla 2 at 59 DAP and peaked at 73 DAP.
- Bihi cultivar recorded higher leaf area/plant than Mogla 1 cultivar at first harvest and peaked at second harvest and declined throughout the pot experiment. The Mogla 1 cultivar produced more leaf area/plant than Bihi cultivar at third harvest and declined to the lowest at seventh harvest at 31 days of PAFH.
- The Mogla 1 cultivar grown under the 30cm x 30cm spacing gave a higher fresh leaf, shoot, and dry leaf yields (t/ha) than Bihi and Mogla 2 cultivars. On fresh and dry weight basis Mogla 1 produced higher leaf blade/stem ratio than Bihi and Mogla 2 cultivars, and acceptable ratios at 30cm x 30cm spacing in the field experiment. The Mogla 1 cultivar is also more leafy on fresh and dry weight basis than Bihi cultivar, and 31 days of PAFH produced a higher dry leaf blade/stem ratio than 38 and 45 days PAFH in the pot experiment.

## 6.2 RECOMMENDATIONS

Based on the results obtained the following recommendations can be considered;

- As a leafy vegetable roselle should be grown at 30cm x 30cm spacing to achieve optimum plant density, yields and acceptable leaf blade/stem and leaf/shoot ratios on both fresh and dry weight basis, if multiple harvesting is to be practised.
- Under harsh conditions, the Mogla 1 cultivar produced relatively more leaf and shoot fresh and dry yields, and was more leafy than Bihi and Mogla 2 cultivars. Hence, Mogla 1 cultivar should be considered when growing roselle under less optimum conditions.
- For optimum yields, 38 days after planting should be considered as appropriate plant age at first harvest for production of roselle as a leafy vegetable by pruning.
- Comparative studies on uprooting and selling of whole plants as against continuous production of roselle as a leafy vegetable by pruning should be done including the cost- benefit analysis to help farmers to make informed choice between the two production systems.
- For continuous harvesting of roselle by pruning, I suggest further studies on the effects of incorporation of chemical and decomposed organic manure into the soil to enhance good yields.
- The experiment should be repeated in both rainy and dry seasons in any of the three Northern regions of Ghana to confirm the present findings.
- Research Institutions in Ghana should embark on vigorous research on roselle to develop improved varieties.

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