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Vegetative Growth and Calyx Yield of Four Roselle (*Hibiscus sabdariffa* L.) Accessions as Influenced by Intra-Row Spacing

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ABSTRACT
The effect of intra-row spacing on vegetative growth and calyx yield of four roselle (*Hibiscus sabdariffa* L.) accessions was determined at the experimental field of the Savannah Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI), Ghana, from August to November, 2016. The split plot design was used with 3 replications. The main plot contained the four roselle accessions ('Samadah', 'Dah rouge', 'Local', and 'Bissap') while the sub-plot contained the four intra-row spacing (30 cm, 40 cm, 50 cm, and 60 cm). An inter-row spacing of 60 cm was maintained. The results showed that yield (fruit dry weight per plant, number of fruits per plant, calyx dry weight) and biomass (fresh and dry shoot weights) were significantly ($P < 0.05$) influenced by intra-row spacing. Intra-row spacing of 50 cm resulted in highest calyx yield across the accessions. Intra-row spacing of 30 cm, 60 cm and 40 cm resulted in high leaf yields in 'Bissap', 'Dah rouge', 'Local' and 'Samadah', respectively. However, intra-row spacing had no significant effect on vegetative attributes of roselle. For calyx production, an intra-row spacing of 50 cm can be used for any of the accessions tested. However, for increased leaf yield, 'Samadah' and 'Local' which are grown for their leaves and calyx could be planted at intra-row spacing of 40 cm and 60 cm, respectively.

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Keywords: *Calyx yield, Roselle Accessions, Intra-row Spacing*

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a traditional African vegetable and it belongs to the family *Malvaceae*. Roselle is one of the most important traditional leafy vegetables cultivated for its health and economic benefits (Atta *et al.*, 2010; Adebooye, 2011). For example, the coloured calyces are used in the pharmaceutical and cosmetic industries (Ibrahim and Hussein, 2006) and in the preparation of herbal drinks, cold and warm beverages, jams and jellies (Tsai *et al*., 2002).

Spacing is crucial in crop production. In general, as plant density increases per unit area, a level is reached at which plants begin to compete for growth factors such as nutrients, sunlight, water, oxygen and carbon dioxide (El Naim *et al*., 2012). In roselle production, the spacing used depends on the purpose of production. For

instance, according to Krishnamurthy *et al.* (1994) biomass yield of roselle (*Hibiscus sabdariffa* L.) decreases with increase in spacing. Albayrak *et al*. (2011) indicated that for most crops, plant density has a major influence on biomass, crop yield and economic profitability. A research on sowing dates, intra-row spacing and the use of nitrogen fertilizer in the production of roselle by Fbabatunde *et al*. (2002) indicated that plant height, canopy diameter and the number of branches per plant were significant among intra-row spacing of 40, 60 and 80 cm, with an intra-row spacing of 80 cm giving the highest value for plant height, canopy diameter and number of branches per plant.

There are many cultivars of most traditional African vegetables which are cultivated throughout Africa and beyond (Norman, 1992). Optimum plant densities depend on characteristics such as growth habit, plant stature and architecture of the genotype (Ibeawuchi *et al*., 2008).

There is, however, little study on accession specific intra-row spacing effect on vegetative and calyx yield of roselle. There is therefore the need for the available roselle accessions to be studied in this regard in order to make good spacing recommendations for their cultivation. The objectives of this study were: 1) To determine the intra-row spacing which will promote the vegetative growth of the roselle accessions, 2) To determine the intra-row spacing which will give high calyx yield of the roselle accessions and 3) To identify accession specific intra-row spacing which will result in maximum leaf and calyx yield of each accession.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the experimental field of the Savannah Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI) at Nyankpala in the Northern region of Ghana. Nyankpala is located in the Tolon District of the Northern region of Ghana at latitude 9° 25′N, longitude 0° 58′W and 183 m above sea level (SARI, 2008).

Climatic Condition of the Study Area

Rainfall is mostly unimodal with about 1000-1200 mm, starting from April to October each year. The area experiences high temperature during the day and is cool at night, with mean monthly minimum temperatures of 23.4 °C and maximum

temperatures of 34.5 °C. The minimum and maximum relative humidity of the area is 46.6% and 76.8%, respectively (SARI, 2008).

Soil Characteristics of the Study Area

The soil of the area is within the voltarian sandstone basin and is sub-classified as Nyankpala series. The savannah soil and savannah achrosols from sand stone parent materials are predominant in the area of study (SARI, 2008).

Experimental Design and Layout

A split-plot design with 3 replications was used for the experiment. The main plot factor was four roselle accessions ('Samadah', 'Dah rouge', 'Local', and 'Bissap') while the sub-plot factor was four intra-row spacings (30 cm, 40 cm, 50 cm and 60 cm).

The inter-row spacing was maintained at 60 cm. The size of each plot was 3.6 m × 2.4 m. Sub-plots were separated from each other by 1 m alley and between main-plots was 1.5 m. The alleys between replications were 2 m wide.

Agronomic Practices

The field was ploughed and harrowed before lining and pegging to demarcate the experimental field into experimental units. Seeds were sown directly at a depth of 2-3 cm, with 5 seeds per hole. Seed sowing took place on 2nd August, 2016. Thinning was done, leaving one plant per stand on the 2nd week after sowing. Weeds were controlled manually by hoeing. The first weeding was carried out on the 3rd week after planting, the second at 6 weeks after planting and the 3rd at 9 weeks after sowing. N. P. K (15-15-15) fertilizer was spot applied on the 2nd week after sowing at a rate of 250 kg/ ha, which was as recommended by Norman (1992). Top dressing was done with Sulphate of Ammonia (21% N) at 125 kg/ ha (Norman, 1992). The experiment was conducted completely under rain fed conditions.

Sampling and Data Collection

Five plants from the inner rows of each plot were randomly sampled and tagged for data collection. Data was collected from the 5th to 11th week after sowing for the following parameters: plant height (cm), stem diameter (cm), number of leaves, branches and fruits per plant, shoot fresh and dry weight (g), average fresh weight

per fruit (g), dry weight of calyx (g) and 1000 seed weight (g). Plant height was determined from the soil level to the terminal growing point of the main stem at weekly intervals, and the average height for each treatment recorded. Stem diameter was determined by using a meter screw gauge. The measurements were taken at 20 cm from the soil level. The number of branches was determined by counting all the branches of the tagged plants and the mean for each treatment was recorded. The number of leaves was determined by counting all the leaves on the tagged plants and the mean number of leaves per plant for each treatment was recorded**.**

Fresh shoots weight was measured at harvest and the shoots were dried under shade until a constant dry weight was obtained for determination of dry weights (g). Seed pods were removed from the freshly harvested fruits leaving the calyces. The fresh calyces were then dried under shade to a constant dry weight and their dry weight recorded. The mean weight (g) of the dry calyx was obtained to know the weight of each dry calyx per plant. One thousand seeds were sampled from harvested pods of each sub- plot and weighed using a sensitive scale (KERN PCB, 10000-1, Kern and Sohn GmbH, Belinen, Germany).

Statistical Analysis

Analysis of variance (ANOVA) in split-plot design model was done using Genstat (9^{th} edition, Lawes Agricultural Trust, Rothamsted Experimental Station, UK) to determine the differences among the accessions, intra-row spacing or their interaction. Mean separation was done using the Fisher's protected LSD at 5% probability.

RESULTS

Effect of Intra-Row Spacing on Vegetative Parameters of Roselle Accessions

Number of Leaves per Plant

The experiment showed no significant ($p > 0.05$) interaction between accession type and intra-row spacing, main effect of intra-row spacing and main effect of accessions on number of leaves per plant at five and six weeks after sowing (data not shown).

Plant Height

There were significant ($p < 0.05$) differences among the accession in plant height at all weeks after sowing. The tallest accessions were 'Local' and 'Bissap' whiles the shortest accessions were 'Samadah' and 'Dah Rouge'. The accessions 'Samadah' and 'Dah Rouge' increased in height from 5 to 9 WAS and became constant thereafter whiles 'Local' and 'Bissap' increased in plant height from 5 to 11 WAS (Figure 1).

Generally, the main effect of intra-row spacing as well as the interaction response of the accessions to intra-row spacing was not significant ($p > 0.05$) for plant height at any of the weeks except at 7 WAS where an interaction was realized between the accessions and intra-row spacing.

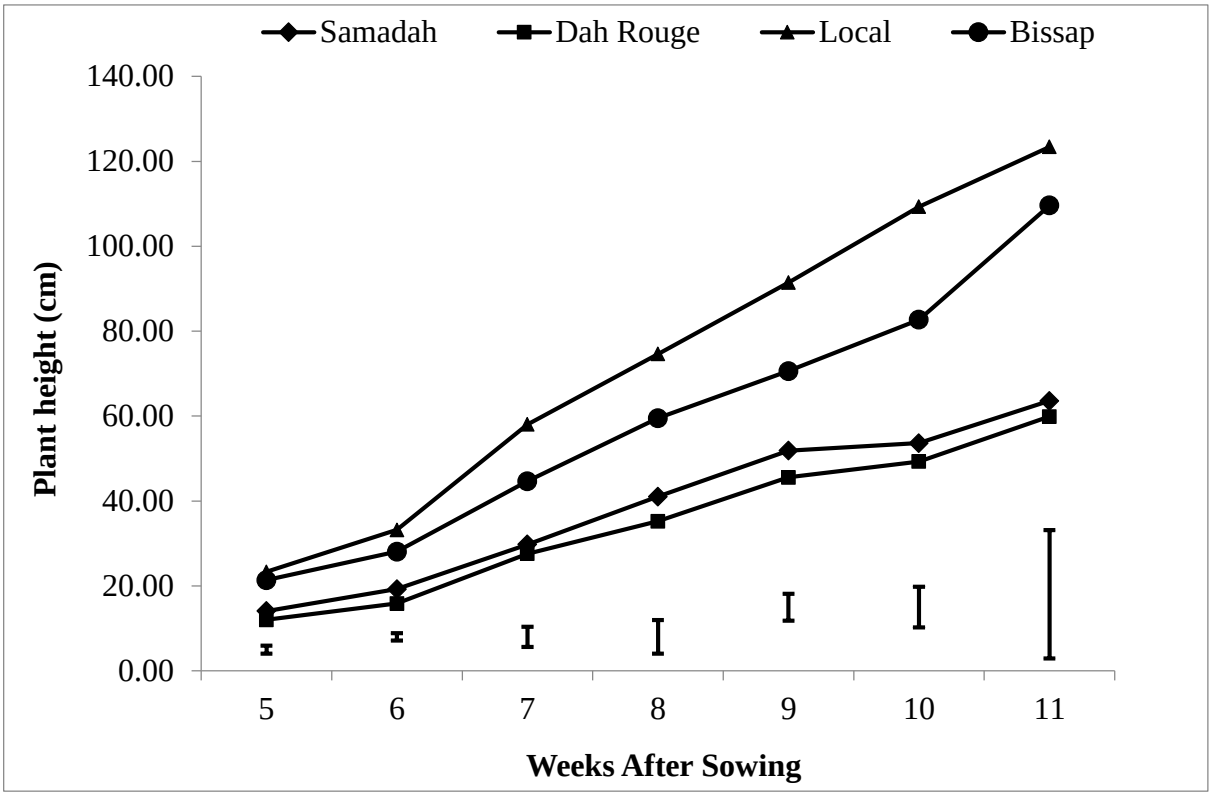

Figure 1: Plant height of different roselle accessions at different weeks after sowing. *Vertical bars are two standard errors of mean differences*.

Stem Diameter

There were no significant ($p > 0.05$) differences among the accession for stem diameter (data not shown). Also neither the main effect of intra-row spacing nor the interaction between intra-row spacing and accession significantly ($p > 0.05$) influenced stem diameter (data not shown).

Number of Branches per Plant

The results showed that, there were significant ($p < 0.05$) differences among the accessions for the number of branches at 5, 7 and 8 WAS but not the other weeks after sowing (Figure 2). The accession with most number of branches at 11 WAS 'Local' whiles 'Samadah', 'Dah Rouge', and 'Bissap' accessions had similar number of branches. Number of branches per plant increased linearly with time in all the accessions except 'Local'. There were significant ($p < 0.05$) effects of intra-row spacing on the number of branches at 8 and 10 WAS but not for the other weeks (Figure 3). The most number of branches per plant was recorded at an intra-row spacing of 60 cm (Figure 2) whereas the other spacing produced similar number of branches.

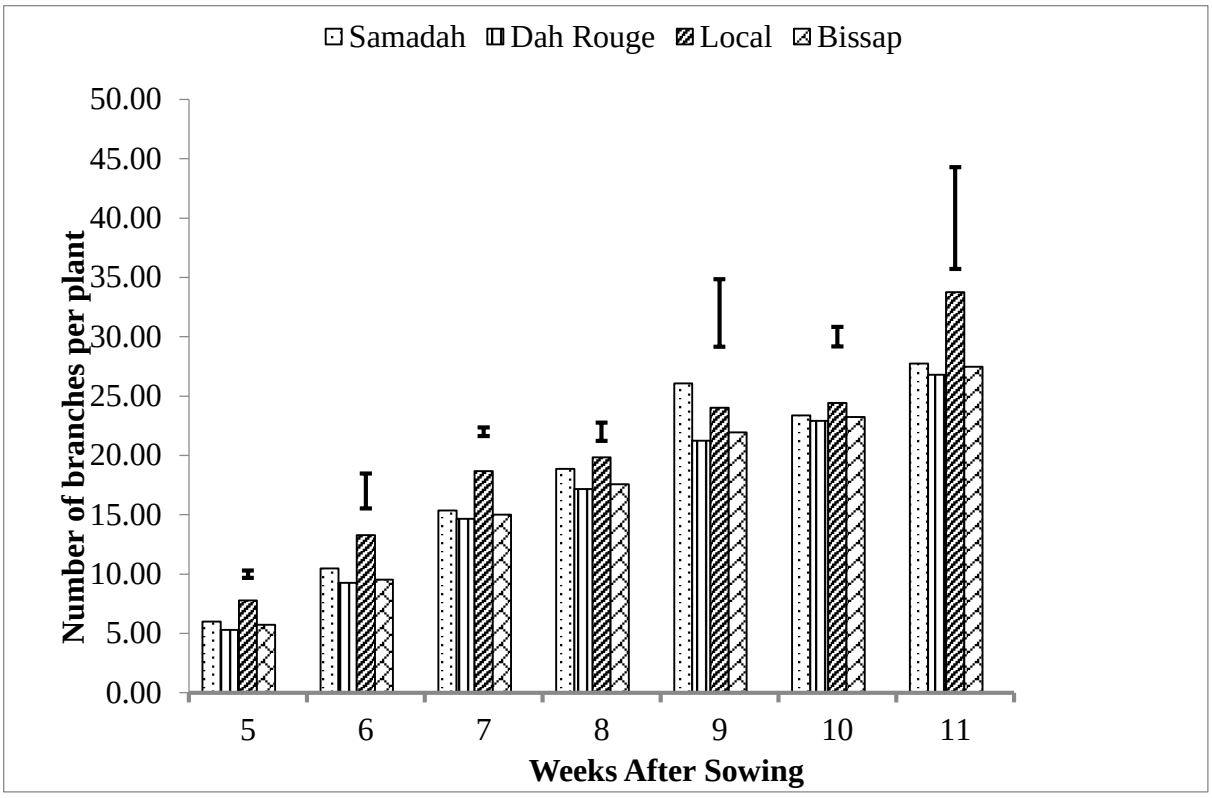

Figure 2: Number of branches per plant of different roselle accessions at different weeks after sowing. *Error bars are two standard errors of mean differences*.

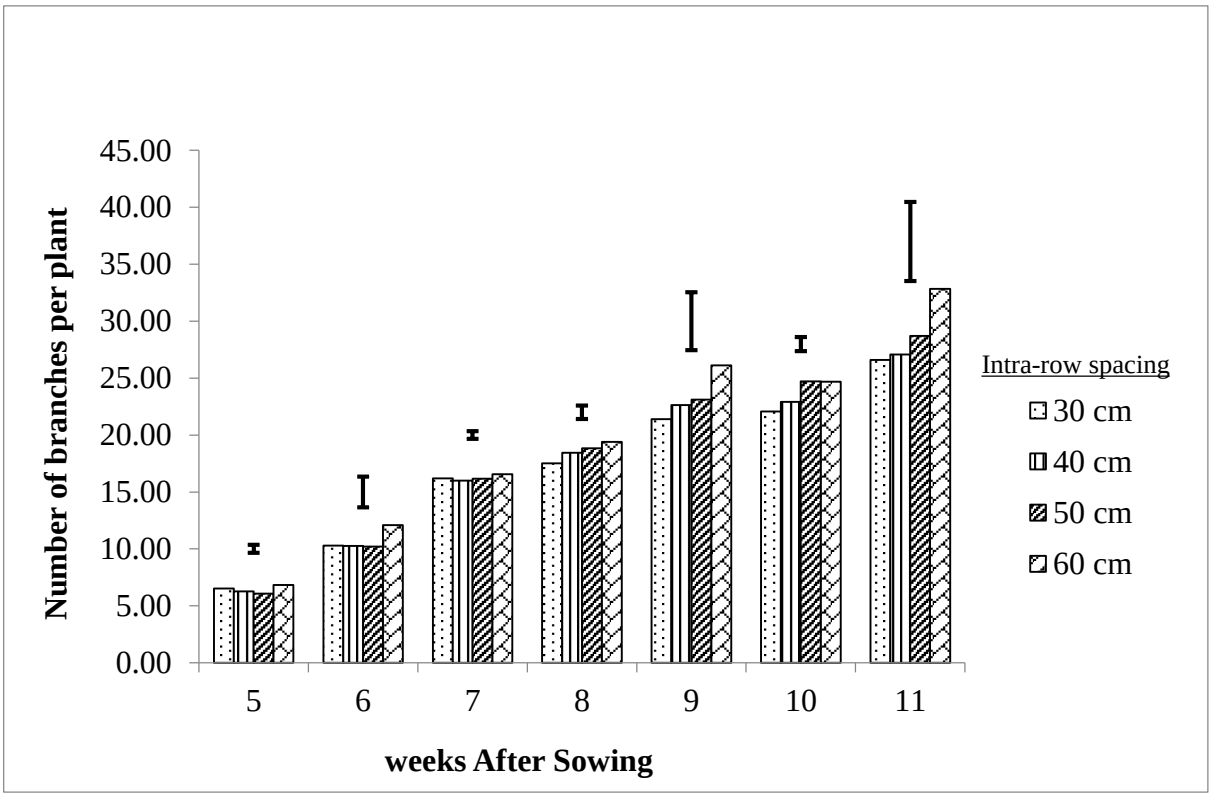

Figure 3: Effect of intra-row spacing on roselle number of branches at different weeks after sowing. *Error bars are two standard errors of mean differences.*

Effect of Intra-row Spacing on Dry Weight of Calyx per Plant.

The results showed that intra-row spacing had significant ($p < 0.05$) effect on calyx dry weight per plant (Figure 4). There was slight similarity in weight at 30 and 40 cm, but 40 cm produced a bit heavier dry calyx than 30 cm. Also, intra-row spacing of 50 cm produced the heaviest dry weight of calyx per plant whiles at 60 cm, there was a reduction in weight.

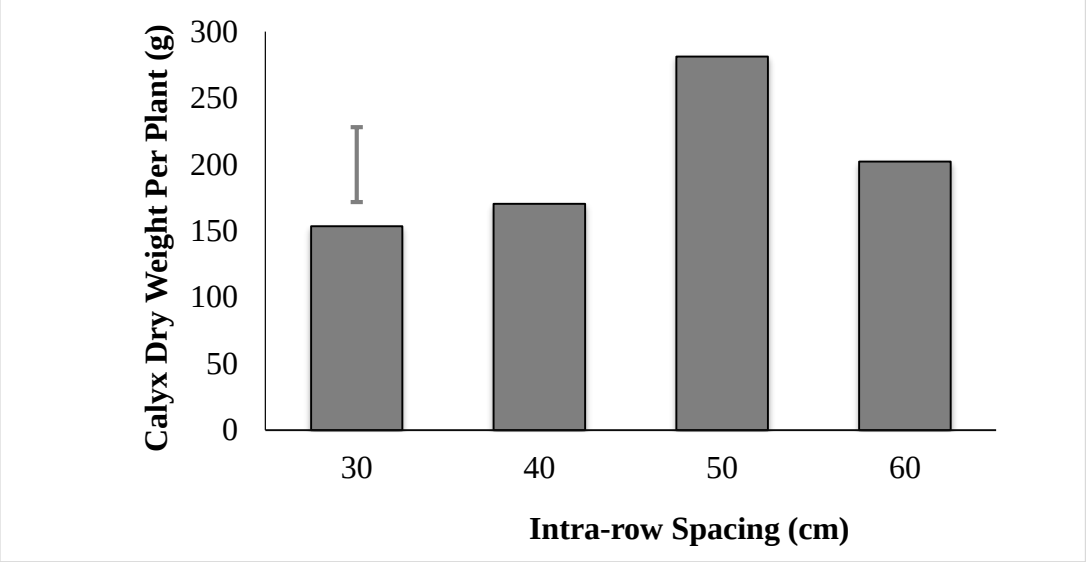

Figure 4: Effect of Intra-Row Spacing on Roselle Calyx Dry Weight per Plant. *A full error bar represents two standard error of mean difference.*

Fruit and Shoot Biomass of Roselle Accessions

The results showed that there were significant ($p < 0.05$) differences among the accessions for average fresh weight per fruit, fruit dry weight per plant and weight of 1000 seeds (Table 1). However, there were no significant ($p < 0.05$) difference among the accessions for number of fruits per plant, shoot fresh and dry weights per plant. The average fresh weight per fruit and fruit dry weight per plant of 'Dah rouge' was significantly lower than that of 'Local' and 'Bissap' but not different from 'Samadah'. The highest number of fruits per plant was recorded by 'Dah Rouge' whereas the highest shoot fresh weight per plant, shoot dry weight per plant and weight of 1000 seeds per plant were recorded by 'Bissap'.

Table 1: Fruit and Shoot Biomass of Roselle Accessions

Accession type	Average fresh weight per fruit (g)	Fruit dry weight/plant (g)	number of fruits/plant (n)	shoot fresh weight/plant (g)	shoot dry weight/plant (g)	1000-seed weight (g)
Samadah	4.10	144.00	35.20	328.00	85.20	15.65
Dah rouge	3.78	142.00	37.20	340.00	88.70	12.75
Local	12.34	291.00	23.70	318.00	89.10	23.65
Bissap	11.64	248.00	21.70	399.00	100.60	26.7
*l.s.d $_{(0.05)}$	0.60	110.30	ns	ns	ns	2.35

*l.s.d is 'least significant difference', 'ns' shows non-significance among the means at $p < 0.05$

Fruit and Biomass Response to Intra-Row Spacing

The results in Table 2 showed that there were significant ($p < 0.05$) effect of the intra-row spacing for all the yield components except average fresh weight per fruit and 1000 seeds weight. The highest average fresh weight per fruit was recorded at an intra-row spacing of 30 cm, while highest 1000 seeds weight was recorded at an intra-row spacing of 40 cm. The highest values for the other parameters were recorded at intra-row spacing of 50 cm. There was an increase in the yield parameters from 30 to 50 cm but a general decline at 60 cm except average fresh weight per fruit and weight of 1000 seeds per plant which did not show any consistent trend.

Table 2: Yield and Shoot Biomass Response of Roselle Accessions to Intra-Row Spacing

Intra-row Spacing label (cm)	Average fresh weight per fruit (g)	Fruit dry weight/plant (g)	number of fruits/plant (n)	shoot fresh weight/plant (g)	shoot dry weight/plant (g)	1000-seed weight (g)
30	8.20	155.00	23.30	269.00	70.20	19.40
40	7.85	176.00	25.80	284.00	73.70	20.20
50	7.95	274.00	37.00	433.00	115.50	19.70
60	7.85	220.00	31.80	400.00	104.20	19.50
*****l.s.d $_{(0.05)}$	ns	66.90	7.63	92.40	18.59	2.50

* l.s.d is 'least significant difference'.

DISCUSSION

Effect of Intra-Row Spacing on Vegetative Attributes of Roselle

The study showed that number of leaves per plant was not affected by intra-row spacing. However, work done by other researchers such as Obodai (2007), Ramos *et al.* (2011) and Degu and Tesfaye (2016) on roselle showed that intra-row spacing significantly influenced number of leaves per plant in roselle. The contrast could be due to differences in the accession or spacing used. There are contrasting reports on the effect of intra-row spacing on plant height. Whereas work on okra (Wenyonu *et al.*, 2011) and roselle (Ramos *et al*., 2011) showed that increase in plant population markedly increases plant height, El Naim *et al*. (2012) showed that crop density has no significant effect on plant height of roselle. In the current study, intra-row spacing did not affect plant height. This might be because even the closest intra-row spacing tested was wide enough to have prevented the intra plant competition which is usually associated with increased plant height due to etiolation. Stem diameter was equally not affected by intra-row spacing. Studies on okra, another traditional African vegetable showed that intra-row spacing had no significant effect on stem diameter (Madisa *et al*., 2015).

Effect of Intra-Row Spacing on Roselle Yield Attributes

Overall, at 60 cm intra-row spacing, there was reduction in all yield parameters. This is because, increasing intra-row spacing leads to a reduction in the number of plants per unit area that could potentially contribute to yield. Additionally, fewer plants give more space for weeds to compete for nutrients (Krishnamurthy *et al*., 1994) and solar radiation (Riar *et al*., 2013) thus leading to lower yields. Only average fresh weight per fruit was highest at 30 cm while 1000-seed weight was also highest at 40 cm intra-row spacing.

The study showed that intra-row spacing had significant effect on calyx dry weight per plant and dry fruit weight per plant. At 50 cm intra-row spacing both indices were highest (Figure 4 and Table 2) and this could probably be attributed to reduced competition of plants for soil nutrient, water, and light for photosynthesis (El Naim *et al.*, 2012) and enhanced photosynthates accumulation in the fruits. Degu and Tesfaye (2016) found showed that 90 cm intra-row spacing produced the highest dry calyx yield per plant while 30 cm produced the least in roselle. The study also showed that intra-row spacing had significant effect on number of fruits per plant. The highest number was recorded at 50 cm intra-row spacing and this result could be due the fact that the plants had less competition for space, soil nutrients and light for photosynthesis. Das and Yaduraju (2011) showed that yield may be reduced in narrow spacing due to increase competition for plant nutrients and soil moisture.

Genotypic Variation in Vegetative Growth and Yield Attributes

Grubben and Denton (2004) indicated that there are differences among roselle cultivars in terms of growth and yield traits. Therefore, differences in plant height, number of branches per plant and 1000-seed weight among the accessions could be attributed to genotypic variations. This finding is in agreement with Atta *et al*. (2011) who also found significant differences among collected accessions of roselle for 100-seed weight which is analogous to 1000-seed weight and other growth attributes. In another study, Ibrahim and Hussein (2006) found that variability exists in some genotypes of roselle for agro-morphological traits of economic importance.

CONCLUSION

The study showed that main effect of intra-row spacing did not significantly influence number of leaves per plant, plant height and stem diameter of roselle but occasionally influenced number of branches per plant at eight and ten weeks after sowing.

Intra-row spacing influenced all yield indices except fresh weight per fruit and 1000-seeds weight. For high calyx yield, intra-row spacing of 50 resulted in the highest yield for all the accessions tested. However, for increased leaf yield, 'Samadah' and 'Local' which are grown for both leaves and calyx could be planted at an intra-row spacing of 40 cm and 60 cm respectively.

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REFERENCES

Adebooye, O.C. (2011). African indigenous vegetables resources in a changing world. In: International Conference on Sustainable Development of Natural Resources of Africa, 5-8 December, 2011, Accra, Ghana.

Albayrak, S., M. Türk, and O. Yüksel. (2011). Effect of row spacing and seeding rate on Hungarian vetch yield and quality. Turkish J. field crops. 16(1):54-58.

Atta, S., Diallo, A.B., Bakasso, Y., Sarr, B., Saadou, M. and Glew, R.H. (2010). Micro-element contents in roselle (*Hibiscus sabdariffa* L.) at different growth stages. African Journal of Food Agriculture Nutrition and Development.10 (5):1-14.

Atta, S., Senye, H.H., Bakasso, Y., Sarr, B., Lona, I. and Saadou, M. (2011). Yield Character Variability in Roselle (Hibiscus sabdariffa L.). African Journal of Agricultural research. Vol. 6 (6)

Babatunde, F.F., Oseni, T.O, Auwalu, B.M., and Udom, G.N. (2002). Effect of sowing dates, intra-row spacings and nitrogen fertilizers on the productivity of red variant roselle (*Hibiscus sabdariffa* L.) Pertanica J.Trop.Agric.Sci.25 (2):99-106.

Das, T.K. and Yaduraju, N.T. (2011). Effects of missing- row sowing supplemented with row spacing and nitrogen on weed competition and growth and yield of wheat. Crop and Pasture Science, 62: 48-57.

Degu, B. and Tesfaye, B. (2016). Effects of inter and intra-row spacing on growth, yield and yield components of Roselle (*Hisbicus sabdariffa* L.). International Journal of Advanced Biology and Biomedical Research 5(1) 260-274

El Naim, A.M., Khaliefa, L.H., Ibrahim, K.A., Ismaeil, F.M.and Zaied, M.B. (2012). Growth and yield of roselle (*Hibiscus sabdariffa* L.) as influenced by population in arid and tropical Sudan under rain fed. International Journal of agriculture and forestry 2(3):88-91.

Grubben, G.H., and Denton, O.A. (2004). Plant Resources of Tropical Africa 2. Vegetables. PROTA FOUNDATION. The Netherlands, Technical Centre for Agriculture and Rural Cooperation.pp:321-327.

Ibeawuchi, I. I, Matthews-Njoku, Edna, Ofor, Miriam O, Anyanwu, Chinyere, P. and Onyia; V. N. (2008). Plant Spacing, Dry Matter Accumulation and Yield of Local and Improved Maize Cultivars. Journal of American Science, 4:1545-1003.

Ibrahim, M.M. and Hussein, R.M. (2006) Variability, habitability and genetic advance in some genotypes of Roselle *(Hibiscus sabdariffa L*.). World J. Agric. Sci. 2: 340-345.

Krishnamurthy, N., Rudraradya, M., Paramesh, R., and Guruj, H. (1994). Effect of closer spacing and nitrogen dressing for higher biomass production in mesta (Hibiscus sabdariffa L.). Karnataka Journal of Agricultural Sciences.7 (2):227-229.

Madisa, E.M., Mathowa, T., Mpofu, C. and Ogame, T.A. (2015). Effects of plant spacing on the Growth, Yield and Yield Components of Okra (*Abelmoschus esculentus* L.) in Botswana. American Journal of Experimental Agriculture. 6(1):7-14

Norman, J.C. (1992). Tropical Vegetable Crops. Arthur H. Stockwell Ltd. Elms Court. Ilfracombe Devon, Great Britain. pp: 183-209.

Obodai, G.A. (2007). A survey and effect of methods of establishment and spacing on the growth and leaf yield of Roselle (*Hibiscus sabdariffa*). Unpublished Master of Science thesis, Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi. 126 PP.

Ramos, D.D., Carmoviera, M., Zarate, N.A.H., Yamanto, N.T., Carnevali, T.O., Souza, N.H., (2011). Spacing between plants with chicken manure in roselle crop. Maringa., 33(4), 695-700.

Riar, R., Wells, R., Edmisten, K.L., Jordan, D. and Bacheler, J. S. (2013). Cotton yield and canopy closure in North Carolina as influenced by row width, plant population, and leaf morphology. Journal of Crop Science, 53(4), 1704-1711

SARI (2008). Savanah Agriculture Research Institute Agro-meteorological unit. Annual report.15 pp.

Tsai, P.J. McIntosh J, Peace P. Camden B. Jordan B.R., (2002). Anthocyanin's and antioxidant capacity in Roselle (Hibiscus sabdariffa L.) extract. Food Research International 35, pp. 351-356.

Wenyonu, D. K., Norman, J. C. Amissah, N. (2011). The effect of apical pruning and spacing on the growth and yield of okra (*Abelmoschus esculentus* (L.) Moench). Ghana Journal of Horticulture, 9, 79-94