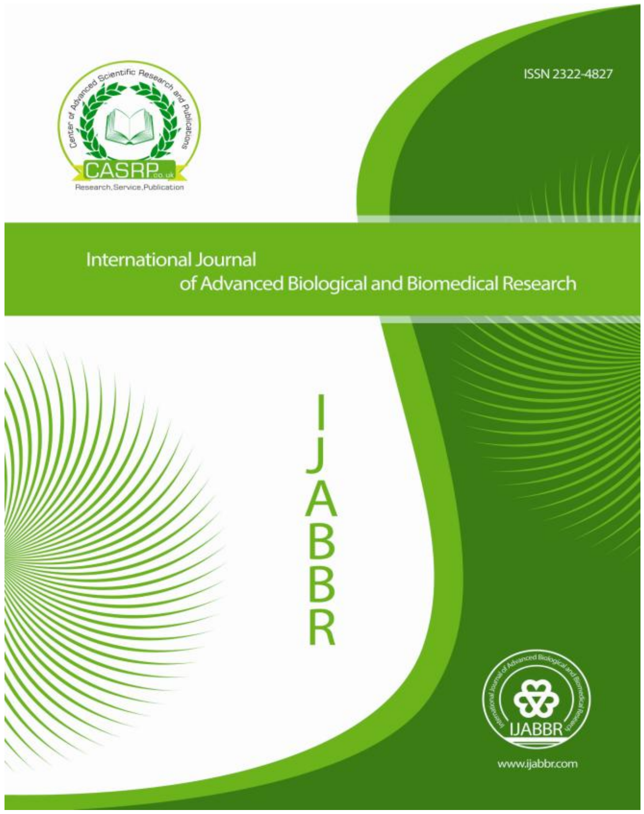
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Effects of inter and intra row spacing on growth, yield and yield components of Roselle (*Hibiscus sabdariffa* L.)

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Abstract

A field experiment was conducted to assess the optimum inter- and intra-row spacing on growth, yield and yield component of Roselle (*Hibiscus sabdariffa* L.) in 2014/15 cropping season at Wondo Genet Agricultural Research Center experimental site (at Wondo Genet station). Two inter-row spacing (60 and 90 cm) and three intra-row spacing (30, 60 and 90 cm) were evaluated using two varieties, WG-Hibiscus-Jamaica and WG-Hibiscus-Sudan on a plot size of 3.6 m length x 4.2 m width. The experimental design was a randomized complete block design in factorial arrangement with 12 treatments in three replications. SAS (version 9) software was used to compute the analysis of variance. The results revealed that varieties differed markedly in most of the studied parameters. Of the two varieties tested, variety WG-Hibiscus-Jamaican showed greater plant height, number of branches per plant, number of leaves/plant, leaf area, leaf area index, days to 50 % flowering, days to 95 % maturity, number of capsules/plant, fresh calyx yield/plant, dry calyx yield/plant, seed yield/plant, total number of capsules/ha, total fresh calyx yield/ha, total dry calyx yield/ha and total seed yield/ha. In contrast, variety WG-Hibiscus-Sudan matures earlier and had heavier 1000 seed weight than variety WG-Hibiscus-Jamaican. The present study demonstrated that, the highest total fresh and dry calyx yield/ha were recorded when WG-Hibiscus-Jamaica and WG-Hibiscus-Sudan were planted at inter-row spacing of 60 cm and intra-row spacing of 30 cm.

Keywords: Hibiscus sabdariffa L., Inter-row spacing, Intra-row spacing, Fresh calyx yield, Dry calyx yield.

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1. Introduction

Roselle (*Hibiscus sabdariffa* L.) is one of the most important annual medicinal shrub that belongs to the family Malvaceae and it is locally known as “Karkade”. This genus has more than 300 species among which, two species of *H.sabdariffa* and *H.altissimia* have been mentioned as an important species (Chen et al., 2002). It is believed to be native of India and later introduced to Malaysia where it is commonly cultivated and might have been carried at an early date to Africa (Morton, 1987). It is known in different countries by various common names, including roselle, razelle, sorrel, red sorrel, Jamaican sorrel, Indian sorrel, Guinea sorrel, sour-sour, and Queensland jelly plant (Mahadevan, 2009). In English-speaking countries, it is known as roselle, Jamaican sorrel, red sorrel, Indian sorrel, rozelle hemp, natal sorrel and rosella. The Japanese name is rohzelu; also sabdriqa or lalambari in Urdu (Kays, 2011); and lal-ambari, patwa or laalambaar in Hindi (Kays, 2011). Roselle is an important cash crop in Western Sudan, particularly in Northern Kordofan State, especially in Elrahad and Um-Rawaba areas (El Naim et al., 2012).

The calyces are widely used to prepare herbal drink, cold and warm beverages, and for making jams and jellies (Tsai et al., 2002). In Africa, they are frequently cooked as a side dish and eaten with pulverized peanuts for stewing as sauce, for making a fine-textured sauce or juice (zobo), syrup, jam, marmalade, relish, chutney or jelly. The seeds are somewhat bitter but have been grounded to a meal for human food in Africa and have also been roasted as a substitute for coffee (Seiyaboh et al., 2013). Red calyces (based on 100 g dry weight) contain 6.4 % protein, 79.3 % carbohydrates, 5.1 % fat, 2.7 % crude fiber, and 6.5 % ash (Nnam and Onyeke, 2003). Roselle is one of the most important and popular medicinal plant which has several properties. The leaves are emollient and are much used in Guinea as a diuretic, refrigerant and sedative (Anhwange et al., 2006) and used to sour the curry or “dal” preparation in Bangladesh as well as the young leaves are used as vegetable (Patil, 2004). The calyx, boiled in water is used as a drink in bilious attacks (Perry, 1980) and has also shown to lower blood pressure (McKay, 2010). The seeds of roselle are used as diuretic, laxative, tonic (Duke, 1985) and to treat debility (Perry, 1980).

In a study on the effect of sowing date and plant density on yield and agronomical traits of roselle in Zabol, Iran, it was reported that the increase in density from 4 to 8 plants/m^2, significantly decrease sepal weight and capsule number per plant, but capsule number per m^2, sepal to capsule weight ratio, sepal yield and biological yield per unit area increased with the increase in plant density (Mir et al., 2011). Gholam and Moosavi (2012) studied the effect of sowing date and plant density on yield and yield components of roselle in Birjan, Iran, it was reported that the increase in density from 8 to 13.3 plants/m^2, fruit number per plant, sepal yield per fruit and plant and single biomass decreased significantly by 29.8, 24.4, 39.1, 55.4 and 33.6 %, respectively, but fruit number/m^2 increased by 18.2%.

In Ethiopia roselle is mainly used to produce healthy juice and herbal tea with full of flavor and tart, due to its high contents of vitamin C and anthocyanins that are found in the calyces. Roselle is predominantly produced by small scale farmers in their homestead garden. Ethiopia has a suitable environment for the production of roselle. But, there are limited findings regarding the modern production technology and to increase productivity to attract the industries or enterprises which are engaged in production and processing of roselle. This is due to lack of knowledge about the crop and limited supply of the crop products. Proper production technology is necessary for productivity of roselle to supply quality product to local or international markets, pharmaceuticals and beverage industries. The crop is produced in traditional management practices by small scale-farmers, depending on rainfall and poor agronomic practices. The main gap in production of the crop is poor agronomic practice such as improper spacing. Considering the enormous benefits of the roselle crop it is necessary to promote its growth and performance in terms of marketable and edible yields by growing it at an optimum spacing. The main yield-limiting factors are information or skill gap on how to produce this crop. Therefore, the study had the following objectives:

General objective to contribute towards improved yield of roselle produced in Ethiopia. Specific objectives to measure growth, yield and yield components of roselle at different inter- and intra-row spacing and to evaluate the interaction between and within inter-, intra-row spacing and varieties in relation to yield and yield components.

2. Materials and methods

The experiment was conducted at Wondo Genet Agricultural Research Center experimental site in Southern Ethiopia during 2014/2015 cropping season. Wondo Genet is located between 7°19' N latitude and 38°38' E longitude; it is found at an altitude of 1780 m.a.s.l (meter above sea level) and receives mean annual rainfall of

1128 mm with minimum and maximum temperature of 11 °C and 26 °C, respectively. The soil textural class of the experimental area is sandy loam with pH of 6.4 (Abayneh et al., 2006).

The seeds of the two varieties; namely, WG-Hibiscus-Jamaica (V1) and WG-Hibiscus-Sudan (V2) were sown on spot directly on the experimental field at two inter-row spacings: 60 and 90 cm and three intra-row spacings 30, 60 and 90 cm after the land prepared well. The experiment was laid out as in a factorial Randomized Complete Block Design (RCBD) with three replications. The plot size was 15.12 m^2 (3.6 m length x 4.2 m width). There were a total of eighteen experimental units for each variety. The distance between each plot and replication was 1 m and 1.5 m, respectively. Sowing was done on 18^{th} of September, 2014. Thinning was done progressively for the seedlings from spot sowing. The first thinning was done 10 days after sowing, to obtain 2 plants per spot. The final thinning was done 17 days after sowing, to have one plant per spot. The field was weeded twice a month starting from seeding until it was established well, the first one after two weeks from sowing and the second at four weeks later. And also the remaining weeding practices, hoeing and watering were made as required.

Data on days to 50 % flowering, days to 95 % physiological maturity, plant height, number of branches/plant, number of leaves/plant, leaf area, leaf area index, number of capsules/plant, fresh calyx yield/plant, dry calyx yield/plant, seed yield/plant, 1000 seed weight, total number of capsules/ha, total fresh calyx yield/ha, total dry calyx yield/ha, total seed yield/ha and harvest index. To statically analyze the differences in characters caused by genotypic and spacing differences, five randomly selected samples were taken from each plot. Mean values of all data for all characters measured were subjected to analysis of variance (ANOVA) using General Linear Model (GLM), statistical analysis software program (SAS Inst, 2002). The Tukey'sStudentized Range (HSD) Test was used to compare the mean separations at 5 % probability level.

3. Results and discussion

3.1. Phenological attributes

3.1.1. Days to 50 % flowering

Analysis of variance revealed that days to 50 % flowering was significantly (P<0.001) affected by variety (Table 1). The higher number of days was recorded at variety WG-Hibiscus-Jamaica; while, the lower number of days was recorded at variety WG-Hibiscus-Sudan (Table 2). In contrast, variety WG-Hibiscus-Jamaica required 51.4 extra more days in order to reach 50 % flowering as compared to variety WG-Hibiscus-Sudan. This could be due to the difference in growth nature of the two varieties. Similar result was reported by Lazim (1973) who showed that differences among cultivars in time to 50 % flowering in sesame.

Intra-row spacing had a significant (P<0.001) effect on days to 50 % flowering (Table 1). The highest number of days was recorded at intra-row spacing of 90 cm; while, the lowest number of days was recorded at intra-row spacing of 30 cm to reach 50 % flowering (Table 2). Days to 50 % flowering increased by increasing intra-row spacing. This could be due to the fact that, in widest intra-row spacing number of plants was less; hence, the competition for light, nutrients, water and space was lower thereby delay in days to 50 % flowering. Similar result was reported by Lazim (1973) on sesame.

Interaction of variety, inter- and intra-row spacing had a significant (P<0.05) effect on days to 50 % flowering (Table 1). The highest number of days to 50 % flowering was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 60 cm and intra-row spacing of 90 cm; whereas, the lowest number of days to 50 % flowering was recorded at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 60 cm and intra-row spacing of 30 cm and also at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 90 cm and intra-row spacing of 30 cm (Table 3). This could be due to the fact that, at wider spacing plant population density was less; hence, the competition for light, nutrients and space was less thereby delay in days to 50 % flowering. Similar result was reported by Alessi et al. (1977) on sunflower. Contrasting results was reported by El Naim et al. (2012) who showed that plant population density had no significant effect on time to 50 % flowering on roselle.

3.1.2. Days to 95 % physiological maturity

Variety had a significant (P < 0.001) effect on days to 95 % physiological maturity (Table 1). The higher number of days was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan to reach 95 % physiological maturity (Table 2). In contrast, WG-Hibiscus-Sudan was matured earlier than WG-Hibiscus-Jamaica. This result is in line with the findings of Lazim (1973)who reported that the differences among cultivars in time to maturity in sesame.

3.2. Growth attributes

3.2.1. Plant height

Plant height was significantly (P<0.001) affected by variety (Table 1). Similar result was reported by Yayeh et al. (2014) on field pea. The higher plant height was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 2).

Interactions of variety, inter- and intra-row spacing had a significant (P < 0.05) effect on plant height (Table 1). The highest plant height was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 60 cm and intra-row spacing of 30 cm; while, the least value was recorded at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 90 cm and intra-row spacing of 60 cm (Table 3). The highest plant height was obtainedat planting of both varieties on closer inter- and closest intra-row spacing combination. This could be due to high competition of plants to light, nutrients, water and space. Supporting evidences were reported by Talukder et al. (2003) on okra, El Naim and Jabereldar (2010) on cowpea, Ramos et al. (2011) on roselle, Wenyonu et al. (2011) on okra, Zewdinesh et al. (2011) on Artemisia annua and Mushayabasa et al. (2014) on okra who stated that an increase in planting population markedly would increase plant height. The tallest plants produced by the most densely populated plants might be attributed to the competition for light and other growth resources among the plants that were crowded at the closer plant spacing (Maurya et al., 2013). Contrasting result obtained by ElNaim et al. (2012) who showed that crop density had no significant effect on plant height of roselle.

3.2.2. Number of branches per plant

Number of branches/plant was significantly (P<0.001) affected by variety (Table 1). The higher number of branches/plant was recorded at variety WG-Hibiscus-Jamaica, while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 2). This could be due to the high vegetative growth nature of variety WG-Hibiscus-Jamaica as compared to WG-Hibiscus-Sudan. Contrasting results was obtained by Brar et al. (2002) and Ali et al. (2009) who reported that variety had non significant results on number of branches in cotton.

3.2.3. Number of leaves per plant

Number of leaves/plant was significantly (P<0.001) affected by variety (Table 1). The higher number of leaves/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 2). Inter-row spacing had a significant (P<0.05) effect on number of leaves/plant (Table 1). The higher number of leaves/plant was recorded at inter-row spacing of 60 cm; while, the lower value was recorded at inter-row spacing of 90 cm (Table 2). Numbers of leaves/plant increased at closer inter-row spacing. Likewise, intra-row spacing had a significant (P<0.001) effect on number of leaves/plant (Table 1). The highest number of leaves/plant was recorded at intra-row spacing of 90 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 2). Numbers of leaves/plant increased consistently by increasing of intra-row spacing. This might be due to reduced competition of plants for light, water and nutrients.

Similarly, interaction of variety with intra-row spacing had a significant (P<0.001) effect on number of leaves/plant (Table 1). The highest number of leaves/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 60 cm (Table 4). Number of leaves/plant was increased at widest intra-row spacing due to reduced competition of plants to light, water and nutrients.

3.2.4. Leaf area/plant

Leaf area/plant was significantly (P<0.001) affected by variety (Table 1). The higher leaf area/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 2). Likewise, intra-row spacing had a significant (P<0.001) effect on leaf area/plant (Table 1). The highest leaf area/plant was recorded at intra-row spacing of 90 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 2). Leaf area/plant increased at increasing of intra-row spacing due to reduced competition of plants to light, water and nutrients. Supporting result was reported by Ijoyah et al. (2010) who observed that leaf area per plant decreased as intra-row spacing reduced on okra.

Similarly, interaction of variety with intra-row spacing exerted a significant (P<0.001) effect on leaf area/plant (Table 1). The highest leaf area/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 30 and 90 cm (Table 4). Leaf area was increased in widest intra-row spacing due to reduced competition of plants to light, water and nutrients. This could have enabled the plants grown at widest intra-row spacing to utilize its energy for the production of a larger leaf area. Similar results were reported by Hossain et al. (2001) and Ijoyah et al. (2010) on okra.

3.2.5. Leaf area index

Leaf area index was significantly (P<0.001) affected by variety (Table 1). The higher leaf area index was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 2). Inter-row spacing had a significant (P<0.05) effect on leaf area index (Table 1). The higher leaf area index was recorded at inter-row spacing of 60 cm; while, the lower value was recorded at inter-row spacing of 90 cm (Table 2). Similarly, intra-row spacing had a significant (P<0.001) effect on leaf area index (Table 1). The highest leaf area index was recorded at intra-row spacing of 30 cm; while, the lowest value was recorded at intra-row spacing of 90 cm (Table 2). Leaf area index increased linearly in closer inter- and closest-intra row spacing due to increased in plant population density per unit area. This could be due to increased in plant competition for light interception for production of assimilates. This result is in line with the findings Bednarz et al. (2000) on cotton who reported that increase leaf area index in response to increasing population density. However, leaf area index was not significantly (P>0.05) affected by interaction of variety with inter- and intra-row spacing; interaction of variety, inter- and intra-row spacing (Table 1).

Table 1

Analysis of variance for growth, phenological and yield attributes of roselle under varying inter and intra row spacing.

SOV	Replication	Variety (V)	R	P	V*R	V*P	R*P	V*R*P	Error	CV (%)
DF	2	1	1	2	1	2	2	2	22	
DFPF	1.17ns	23758.97***	0.6 ns	14.45***	0.52ns	2.34ns	2.38ns	3.84*	0.87	0.96
DNFPM	75.29ns	26645.84***	3.01ns	15.68ns	1.14ns	2.18ns	130.01ns	123.61ns	39.88	3.57
PH	137.76ns	16630.1***	160.29ns	211.58ns	81.44ns	181.35ns	639.35*	574.01*	120.33	10.77
NBPP	18.48*	960.27***	0.02ns	1.81ns	5.83ns	3.17ns	1.18ns	8.94ns	3.46	14.5
NLPP	5971.89ns	4116270.33***	45555.7*	194257.2***	22102ns	199233.33***	4316.48ns	11287.43ns	6564.42	16.45
LA	0.00009ns	0.67***	0.005ns	0.08***	0.0004ns	0.07***	0.004ns	0.006ns	0.003	23.94
LAI	0.054ns	1.21***	0.55*	2.6***	0.02ns	0.16ns	0.04ns	0.02ns	0.075	11.35
NCPP	2627.66*	44380.46***	1538.06ns	4456.43**	2789.44*	4518.36**	2523*	1277.6ns	627.36	29.15
FCYPP	7314.67ns	489577.99***	2313.53ns	49750.3***	68232.2***	42964.27***	25310.54**	26297.23**	4285.97	25.51
DCYPP	40.47ns	5677.64***	3.74ns	416.8**	646.02**	473.5***	336.16**	360.52**	46.82	24.62
SYPP	435.17ns	10252.47***	608.33ns	1053.75**	425.17ns	1323.73**	739.44ns	133.47ns	175.59	30.17
TSW	1.06ns	1870.36***	3.88ns	0.22ns	0.02ns	0.42ns	0.41ns	5.73*	1.22	3.71
NCPH	1.7577205E12ns	2.1836745E13***	3.4481788E12*	7.7356249E12***	1130198057ns	53454439137ns	2.6773488E12*	594413070472ns	5.08828E+11	31.35
FCYPH	5177799.5ns	232986115.6***	43781315.1***	51592203.3***	6335712.4ns	617898.6ns	23614967.2**	13068387.8*	2726611.9	24.59
DCYPH	15483.75ns	2832111.95***	576129.05**	805447.88***	27643.68ns	29236.85ns	252829.81*	204924.17*	46626.01	29.21
SYPH	0.19ns	5.26***	0.57ns	2.33***	0.0004ns	0.06ns	0.68*	0.033ns	0.15	33.13
HI	2.35ns	24.76ns	39.91ns	24.53ns	25.74ns	55.89*	4.01ns	26.39ns	11.6	23.75

Where, SOV = source of variance, R = Inter-row spacing, P = Intra-row spacing, DFPF = Days to 50 % flowering, DNFPM = Days to 95 % physiological maturity, PH = Plant height (cm), NBPP = Number of branches/plant, NLPP = Number of leaves/plant, LA = Leaf area/plant (m^2), LAI= Leaf area index, NCPP = Number of capsules/plant, FCYPP = Fresh calyx yield/plant (g), DCYPP = Dry calyx yield plant/plant (g), SYPP = Seed yield/plant (g) and TSW = 1000 seed weight (g), NCPH= Total number of capsules/ha, FCYPH= Total fresh calyx yield (kg/ha), DCYPH= Total dry calyx yield (kg/ha), SYPH= Total seed yield (t/ha), HI= Harvest index (%),*** = significant at 0.001 level of probability, ** = significant at 0.01 level of probability, * = significant at 0.05 level of probability and ns= non significant at 0.05 level of probability.

Table 2
Effects of variety, inter- and intra-row spacing on the phenological and growth attributes of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and	Mean growth and phenological attributes						
statistics	DFPF	DNFPM	PH (cm)	NBPP	NLPP	LA (m^2)	LAI
Variety							
WG-Hibiscus-Jamaica	122.3a	204.1a	123.36a	17.99a	830.65a	0.36a	2.59a
WG-Hibiscus-Sudan	70.92b	149.69b	80.37b	7.66b	154.37b	0.1b	2.22b
CD $_{0.05}$	0.64	4.37	7.58	1.29	56.01	0.04	0.19
Inter-RS (cm)							
60	96.48	176.61	103.98	12.85	528.08a	0.24	2.53a
90	96.73	177.19	99.76	12.81	456.94b	0.22	2.28b
CD $_{0.05}$	ns	ns	ns	Ns	56.01	ns	0.19
Intra-RS (cm)							
30	95.50c	175.92	104.02	12.39	346.73b	0.15b	2.90a
60	96.63b	176.62	97.03	13.12	549.64a	0.25a	2.35b
90	97.69a	178.15	104.55	12.97	581.16a	0.30a	1.97c
CD $_{0.05}$	0.95	ns	ns	Ns	83.09	0.06	0.28
CV (%)	0.96	3.57	10.77	14.50	16.45	23.94	11.35

Means followed by the same letter in the same column are not significantly different at 5% probability level using Tukey's Studentized Range (HSD) Test. ns= non significant at 5 % probability level, RS= Row spacing, DEPF= Days to 50 % flowering, DNFPPM= Days to 95 % physiological maturity, PH= Plant height, NBPP= Number of branches/plant, NLPP= Number of leaves/plant, LA= Leaf area, LAI= Leaf area index and CD= Critical difference.

3.3. Yield attributes

3.3.1. Number of capsules per plant

Number of capsules/plant was significantly (P<0.001) affected by variety (Table 1). The higher number of capsules/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 5).

Likewise, intra-row spacing exerted a significant (P<0.01) effect on number of capsules/plant (Table 1). The highest number of capsules/plant was recorded at intra-row spacing of 60 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 5). Number of capsules/plant was increased at wider intra-row spacing due to less competition of plants for growth resources. Similar result was reported by Singh and yadav (1987) on sesame; Ijoyah et al. (2010) on okra; Aluko et al. (2011) on kenaf and Jan et al. (2014) on sesame. Interaction of variety with inter-row spacing had a significant (P<0.05) effect on number of capsules/plant (Table 1). The highest number of capsules/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with inter-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with inter-row spacing of 90 cm (Table 4). Number of capsules/plant was increased by increasing of inter-row spacing in WG-Hibiscus-Jamaica and by decreasing of inter-row spacing in WG-Hibiscus-Sudan. This could be due to the difference in growth nature of the varieties. Likewise, number of capsules/plant was significantly (P<0.01) affected by interaction of variety with intra-row spacing (Table 1). The highest number of capsules/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 90 cm (Table 4). Number of capsules/plant increased at WG-Hibiscus-Jamaica by increasing of intra-row spacing. This could be due to less competition of plants for light, water and nutrients that enabled plants to utilize its energy for maximum capsule development. Similar result was reported by Yakubu et al. (2006) on roselle. But, number of capsules/plant increased by increasing intra-row spacing up to 60 cm in WG-Hibiscus-Sudan. This might be due to the growth nature of less demand of the variety to extra wide intra-row spacing which is more than 60 cm for maximum capsule development.

Table 3
Interaction effects of variety, inter- and intra-row spacing on days to 50 % flowering, plant height, fresh and dry calyx yield/plant of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	Mean phenological, growth and yield attributes			
	DFPF (DAS)	PH (cm)	FCYPP (g)	DCYPP (g)
Variety*inter-RS*intra-RS				
V1*60 cm*30 cm	121b	140.47a	258.45bc	29.69bc
V1*60 cm*60 cm	121b	114.76abc	258.93bc	29.58bc
V1*60 cm*90 cm	124.9a	125.69ab	447.64ab	23.80cd
V1*90 cm*30 cm	121b	104.33bcd	210.43c	23.33cd
V1*90 cm*60 cm	123ab	119.78ab	563.69a	61.82a
V1*90 cm*90 cm	122.9ab	135.11ab	500.22a	49.59ab
V2*60 cm*30 cm	70c	86.07cde	155.48c	16.69cd
V2*60 cm*60 cm	71c	84.13cde	169.52c	16.97cd
V2*60 cm*90 cm	71c	72.73de	201.54c	23.8cd
V2*90 cm*30 cm	70c	85.20cde	115.63c	15.11cd
V2*90 cm*60 cm	71.5c	69.43e	108.31c	10.19cd
V2*90 cm*90 cm	72c	84.67cde	89.48c	8.6d
Mean	96.61	101.86	256.61	25.76
$CD_{0.05}$	2.76	32.58	194.44	20.32
CV (%)	0.96	10.77	25.51	24.62

Means followed by the same letter in the same column are not significantly different at 5% probability level using Tukey's Studentized Range (HSD) Test. RS= Row spacing, DEPF= Days to 50 % flowering (days after sowing), PH= Plant height, FCYPP= Fresh calyx yield/plant, DCYPP= Dry calyx yield/plant and CD= Critical difference.

Table 4
Interaction effects of variety with inter- and intra-row spacing on leaf area/plant and number of capsules/plant of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	Variety					
	Leaf area/plant (m^2)			Number of capsules/plant		
	V1	V2	Mean	V1	V2	Mean
Inter-RS (cm)						
60	0.38	0.10	0.24	105.71a	53.09b	79.4
90	0.35	0.09	0.22	136.38a	48.56b	92.47
Mean	0.37	0.10		121.05	50.83	
$CD_{0.05}$		Ns			32.79	
Intra-RS (cm)						
30	0.20b	0.09c	0.15	78.18b	49.47b	63.83
60	0.41a	0.10bc	0.26	137.33a	60.96b	99.15
90	0.51a	0.09c	0.30	147.63a	42.04b	94.84
Mean	0.37	0.09		121.05	50.82	
$CD_{0.05}$		0.1			45.05	
CV (%)		23.94			29.15	

Means followed by the same letter in the same column are not significantly different at 5 % probability level using Tukey`sStudentized Range (HSD) Test. ns= non significant at 5 % probability level, RS= Row spacing and CD= Critical difference.

Table 5
Effects of variety, inter- and intra-row spacing on yield attributes of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	Mean yield attributes				
	NCPP	FCYPP (g)	DCYPP (g)	SYPP (g)	TSW (g)
Variety					
WG-Hibiscus-Jamaica	121.05a	373.23a	40.35a	60.79a	22.53b
WG-Hibiscus-Sudan	50.82b	139.99b	15.24b	27.04b	36.94a
Mean	85.94	256.61	27.80	43.92	29.74
CD $_{0.05}$	17.32	45.26	4.73	9.16	0.76
Inter-RS (cm)					
60	79.40	248.59	27.47	39.81	29.41
90	92.47	264.63	28.12	48.03	30.06
Mean	85.94	256.61	27.80	43.92	29.74
CD $_{0.05}$	ns	ns	ns	Ns	ns
Intra-RS (cm)					
30	63.82b	185.00b	21.20b	33.48b	29.82
60	99.14a	275.12a	29.62a	51.59a	29.58
90	94.84a	309.72a	32.56a	46.69ab	29.81
Mean	85.93	256.61	27.79	43.92	29.74
CD $_{0.05}$	25.69	67.14	7.02	13.59	Ns
CV (%)	29.15	25.51	24.62	30.17	3.71

Means followed by the same letter in the same column are not significantly different at 5% probability level using Tukey's Studentized Range (HSD) Test. ns= non significant at 5 % probability level, NCPP= Number of capsules/plant, FCYPP= Fresh calyx yield/plant, DCYPP= Dry calyx yield/plant, SYPP= Seed yield/plant, TSW= 1000 seed weight and CD= Critical difference.

3.3.2. Fresh calyx yield per plant

Fresh calyx yield/plant was significantly (P<0.001) affected by variety (Table 1). The higher fresh calyx yield/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 5). Intra-row spacing had a significant (P<0.01) effect on fresh calyx yield/plant (Table 1). The highest fresh calyx yield/plant was recorded at intra-row spacing of 90 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 5). Fresh calyx yield/plant increased consistently with increasing of intra-row spacing. This could be due to the fact that in wider spacing there was less competition of plants for light, nutrient and water thereby plants could able to produced maximum fresh calyx yield/plant. Supporting result was reported by El Naim et al. (2012) who stated that calyces yield/plant increases gradually with increasing of plant spacing in roselle.

Interaction of variety with inter-row spacing exerted a significant (P<0.001) effect on fresh calyx yield/plant (Table 1). The highest fresh calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with inter-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with inter-row spacing of 90 cm (Table 6). Fresh calyx yield/plant increased by increasing of inter-row spacing in WG-Hibiscus-Jamaica. This could be due to reduced competition of plants between the hills for available growth resources such as light, water and nutrients. But in the case of WG-Hibiscus-Sudan, fresh calyx yield/plant increased by decreasing of inter-row spacing. This could be due to favorable growth conditions of the spacing.

Similarly, interaction of variety with intra-row spacing exerted a significant (P<0.001) effect on fresh calyx yield/plant (Table 1). The highest fresh calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 30 cm (Table 6). Fresh calyx yield/plant increased linearly by increasing intra-row spacing due to less competition of plants for light, nutrients and space. This result is in line with the finding of El Naim et al. (2012) on roselle.

The combined statistical analysis demonstrated that, fresh calyx yield/plant was significantly (P<0.01) affected by interaction of variety, inter- and intra-row spacing (Table 1). The highest fresh calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 90 cm and intra-row spacing of 60 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 90 cm and intra-row spacing of 60 cm (Table 3). Fresh calyx yield/plant increased by decreasing plant population density in WG-Hibiscus-Jamaica due to less competition of plants for light, nutrients and space. But in case of WG-Hibiscus-Sudan, fresh calyx yield/plant increased linearly by decreasing inter-row spacing and by increasing of intra-row spacing. This could be due to favorable growth conditions of inter- and intra-row spacing combinations for maximum fresh calyx development.

3.3.3. Dry calyx yield per plant

Dry calyx yield/plant was significantly (P<0.001) affected by variety (Table 1). The higher dry calyx yield/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 5). Likewise, intra-row spacing had a significant (P<0.01) effect on dry calyx yield/plant (Table 1). The highest dry calyx yield/plant was recorded at intra-row spacing of 90 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 5). Dry calyx yield/plant increased by increasing of intra-row spacing due to reduced competition of plants to light, nutrient, water and space. This result is in line with the finding of El Naim et al. (2012) who stated that calyces yield/plant increases gradually with increasing of plant spacing in roselle.

Interaction of variety with inter-row spacing exerted a significant (P<0.01) influence on dry calyx yield/plant (Table 1). The highest dry calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with inter-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with inter-row spacing of 90 cm (Table 6). Dry calyx yield/plant increased by increasing of inter-row spacing in WG-Hibiscus-Jamaica. This could be due to reduced competition of plants between the hills for available growth resources. Nevertheless, in the case of WG-Hibiscus-Sudan, dry calyx yield/plant increased by decreasing of inter-row spacing. This could be due to favorable growth conditions of the spacing.

Dry calyx yield/plant was significantly (P<0.001) affected by interaction of variety with intra-row spacing (Table 1). The highest dry calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan in intra-row spacing of 60 cm (Table 6). Dry calyx yield/plant increased at widest intra-row spacing due to reduced competition of plants to light, nutrient, water and space.

Similarly, interaction of variety, inter- and intra-row spacing had a significant (P<0.01) effect on dry calyx yield/plant (Table 1). The highest dry calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with inter-row spacing of 90 cm and intra-row spacing of 60 cm; whereas, the lowest dry calyx yield/plant was recorded at interaction of variety WG-Hibiscus-Sudan with inter-row spacing of 90 cm and intra-row spacing of 90 cm (Table 3). Dry calyx yield/plant increased by decreasing of plant population density due to less competition of plants for light, nutrients, water and space in WG-Hibiscus-Jamaica. But in case of WG-Hibiscus-Sudan, dry calyx yield/plant increased linearly by decreasing of inter-row spacing and by increasing of intra-row spacing. This could be due to favorable growth conditions of inter- and intra-row spacing combinations for maximum dry calyx yield production.

3.3.4. Seed yield per plant

Seed yield/plant was significantly (P<0.001) affected by variety (Table 1). The highest seed yield/plant was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 5). Similarly, intra-row spacing had a significant (P<0.01) effect on seed yield/plant (Table 1). The highest seed yield/plant was recorded at intra-row spacing of 60 cm; while, the lowest value was recorded at intra-row spacing of 30 cm (Table 5). Seed yield/plant increased at wider intra-row spacing due to less competition of plants for light, water and nutrients. Supporting result was reported by Rahnama and Bakhshandeh (2006), who observed that seed weight/plant was increased by increasing plant distance up to 60 cm on sesame. Contrasting result was reported by Uzun et al. (2012) who detected that seed yield was not affected by intra-row spacing in canola.

Interaction of variety with intra-row spacing had a significant (P<0.01) effect on seed yield/plant (Table 1). The highest seed yield/plant was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 90 cm (Table 7). Seed yield/plant increased linearly by increasing of intra row spacing in WG-Hibiscus-Jamaica. Supporting result was reported by Haruna (2011) who observed that highest seed yield per plant was recorded at 30 cm intra row spacing compared with those recorded at 7.5 and 15 cm in sesame. But in the case of WG-

Hibiscus-Sudan, seed yield/plant increased linearly by increasing of intra row spacing up to 60 cm. This could be due the favorable growth condition of the spacing.

Table 6
Interaction effects of variety with inter- and intra-row spacing on fresh calyx yield/plant and dry calyx yield/plant of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	Variety					
	Fresh calyx yield/plant (g)			Dry calyx yield/plant (g)		
	V1	V2	Mean	V1	V2	Mean
Inter-RS (cm)						
60	321.68b	175.51c	248.60	35.80b	19.15c	27.48
90	424.78a	104.48c	264.63	44.91a	11.32c	28.12
Mean	373.23	140.00		40.36	15.24	
CD $_{0.05}$	85.7			8.96		
Intra-RS (cm)						
30	234.44b	135.55b	185.00	26.51b	15.90bc	21.21
60	411.31a	138.92b	275.12	45.67a	13.58bc	29.63
90	473.93a	145.51b	309.72	48.88a	16.24c	32.56
Mean	373.23	139.99		40.35	15.24	
CD $_{0.05}$	117.74			12.31		
CV (%)	25.51			24.62		

Means followed by the same letter in the same column are not significantly different at 5 % probability level using Tukey's Studentized Range (HSD) Test. CD= Critical difference.

3.3.5. 1000-seed weight

1000 seed weight was significantly (P<0.001) influenced by variety (Table 1). The higher 1000-seed weight was recorded at variety WG-Hibiscus-Sudan; while, the lower value was recorded at variety WG-Hibiscus-Jamaica (Table 5). This could be due to the difference in seed size and weight of the varieties.

1000-seed weight was significantly (P<0.05) affected by interaction of variety, inter- and intra-row spacing (Table 1). The highest 1000 seed weight was recorded at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 90 cm and intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 60 cm and intra-row spacing of 60 cm (Table 8). 1000-seed weight increased at lowest plant population density in WG-Hibiscus-Sudan due to the fact that reduced competition of plants for light, water and nutrient could able to produce highest 1000-seed weight. But in case of WG-Hibiscus-Jamaica, 1000 seed weight increased at the prescribed spacing. This could be due to favorable growth conditions of the spacing for maximum seed weight. Contrasting results were reported by Jakusko et al. (2013) on sesame and Yayeh et al. (2014) on field pea.

3.3.6. Total number of capsules per hectare

Total number of capsules/ha was significantly (P<0.001) affected by variety (Table 1). The higher total number of capsules/ha was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 9).

Inter-row spacing exerted a significant (P<0.05) effect on total number of capsules/ha (Table 1). The highest total number of capsules/ha was recorded at inter-row spacing of 60 cm; while, the lowest value was recorded at inter-row spacing of 90 cm (Table 9). Total number of capsules/ha was increased at closer inter-row spacing. This could be due to increased in number of plants per unit area attributed to an increase in total number of capsules/ha.

Table 7
Interaction effects of variety with inter- and intra-row spacing on seed yield/plant and harvest index of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	Variety					
	Seed yield/plant (g)			Harvest index (%)		
	V1	V2	Mean	V1	V2	Mean
Inter-RS (cm)						
60	53.25a	26.37b	39.81	13.74	17.09	15.42
90	68.34a	27.72b	48.03	13.32	13.29	13.31
Mean	60.80	27.05		13.53	15.19	
CD $_{0.05}$	17.35			ns		
Intra-RS (cm)						
30	42.12bc	24.83cd	33.48	10.92c	15.28ab	13.1
60	64.87ab	38.32cd	51.60	15.72ab	12.41ab	14.07
90	75.40a	17.98d	46.69	13.94ab	17.88a	15.91
Mean	60.80	27.04		13.53	15.19	
CD $_{0.05}$	23.83			6.13		
CV (%)	30.17			23.75		

Means followed by the same letter in the same column are not significantly different at 5 % probability level using Tukey's Studentized Range (HSD) Test. ns= non significant at 5 % probability level, RS= Row spacingand CD= Critical difference.

Likewise, total number of capsules/ha was significantly (P<0.001) affected by intra-row spacing (Table 1). The highest total number of capsules/ha was recorded at intra-row spacing of 30 cm; while, the lowest value was recorded at intra-row spacing of 90 cm (Table 9). Total number of capsules/ha increased by decreasing of intra-row spacing. This could be due to increased in number of plants per unit area attributed to an increase in total number of capsules/ha.

3.3.7. Total fresh calyx yield per hectare

Total fresh calyx yield/ha was significantly (P<0.001) affected by variety (Table 1). The higher total fresh calyx yield/ha was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 9). Inter-row spacing exerted a significant (P<0.001) effect on total fresh calyx yield/ha (Table 1). The higher total fresh calyx yield was recorded at inter-row spacing of 60 cm; while, the lower value was recorded at inter-row spacing of 90 cm (Table 9). Total fresh calyx yield/ha increased in closer inter-row spacing. This could be due to the fact that high population density per unit area attributed to the increase in total fresh calyx yield/ha. Similarly, total fresh calyx yield/ha was significantly (P<0.001) affected by intra-row spacing (Table 1). The highest total fresh calyx yield/ha was recorded at intra-row spacing of 30 cm; while, the lowest value was recorded at intra-row spacing of 90 cm (Table 9). Total fresh calyx yield/ha increased in closest intra-row spacing. This could be due to the fact that high population density per unit area attributed to the increase in total fresh calyx yield/ha.

Interaction of variety, inter- and intra-row spacing exerted a significant (P<0.05) effect on total fresh calyx yield/ha (Table 1). The highest total fresh calyx yield/ha was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 60 cm and intra-row spacing of 30 cm; whereas, the lowest value was recorded at interaction of variety WG-Hibiscus-Sudan, inter-row spacing of 90 cm and intra-row spacing of 90 cm (Table 8). In closest spacing (60 cm x 30 cm) total fresh calyx yield/ha was increased by 54.85 % in WG-Hibiscus-Jamaica and 86.29% in WG-Hibiscus-Sudan as compared to widest spacing (90 cm x 90 cm). Total fresh calyx yield/ha increased by increasing plant population density per unit area. This could be due to the fact that high population density per unit area attributed to the increase in total fresh calyx yield/ha.

3.3.8. Total dry calyx yield per hectare

Total dry calyx yield/ha was significantly (P<0.001) affected by variety (Table 1). The higher total dry calyx yield/ha was recorded at variety WG-Hibiscus-Jamaica; while, the lower value was recorded at variety WG-Hibiscus-Sudan (Table 9). Inter-row spacing exerted a significant (P<0.01) effect on total dry calyx yield/ha (Table

1). The higher total dry calyx yield/ha was recorded at inter-row spacing of 60 cm; while, the lower value was recorded at inter-row spacing of 90 cm (Table 9). Total dry calyx yield/ha increased in closer inter-row spacing. This could be due to the fact that high population density per unit area attributed to the increase in total dry calyx yield/ha.

Table 8

Interaction effects of variety, inter- and intra-row spacing on 1000 seed weight, total fresh calyx yield/ha and dry calyx yield/ha of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	**Mean yield attributes**		
Variety*inter-RS*intra-RS	**TSW (g)**	**FCYPH (kg)**	**DCYPH (kg)**
V1*60 cm*30 cm	21.93b	14359a	1649.3a
V1*60 cm*60 cm	21.73b	7193bcd	819.9bcd
V1*60 cm*90 cm	22.85b	8275bcd	886.5bc
V1*90 cm*30 cm	23.27b	8350bcd	925.9bc
V1*90 cm*60 cm	23.40b	10893ab	1196.4ab
V1*90 cm*90 cm	21.98b	6483bcde	640.6bcde
V2*60 cm*30 cm	36.64a	8638bc	927.0bc
V2*60 cm*60 cm	37.08a	4709cdef	471.3cde
V2*60 cm*90 cm	36.21a	3732def	440.7cde
V2*90 cm*30 cm	37.45a	4588cdef	599.5bcde
V2*90 cm*60 cm	36.11a	2173ef	199.5de
V2*90 cm*90 cm	38.18a	1184f	114.8e
Mean	29.74	6714.75	739.28
CD $_{0.05}$	3.28	4904.3	641.33
CV (%)	3.71	24.59	29.21

Means followed by the same letter in the same column are not significantly different at 5% probability level using Tukey`sStudentized Range (HSD) Test. RS= Row spacing, TSW= 1000 seed weight, FCYPH= Total fresh calyx yield/ha, DCYPH= Total dry calyx yield/ha and CD= Critical difference.

Likewise, total dry calyx yield/ha was significantly (P<0.001) affected by intra-row spacing (Table 1). The highest total dry calyx yield/ha was recorded at intra-row spacing of 30 cm; while, the lowest value was recorded at intra-row spacing of 90 cm (Table 9). Total dry calyx yield/ha increased in closest intra-row spacing. This could be due to the fact that high population density per unit area attributed to the increase in total dry calyx yield/ha.

Interaction of variety, inter- and intra-row spacing had a significant (P<0.05) effect on total dry calyx yield/ha (Table 1). The highest total dry calyx yield/ha was recorded at interaction of variety WG-Hibiscus-Jamaica, inter-row spacing of 60 cm and intra-row spacing of 30 cm; while, the lowest value was recorded at interaction of variety WG-*Hibiscus*-Sudan, inter-row spacing of 90 cm and intra-row spacing of 90 cm (Table 8). In closest spacing total dry calyx yield/ha was increased by 61.16 % in WG-Hibiscus-Jamaica and 87.62 % in WG-Hibiscus-Sudan as compared to widest spacing (90 cm x 90 cm). This could be due to the fact that high population density per unit area attributed to the increase in total dry calyx yield/ha.

3.3.9. Total seed yield per hectare

Total seed yield/ha was significantly (P<0.001) affected by variety (Table 1). The higher total seed yield/ha was recorded at variety WG-Hibiscus-Jamaica; while the lower value was recorded at variety WG-Hibiscus-Sudan (Table 9). Likewise, intra-row spacing exerted a significant (P<0.001) effect on total seed yield/ha (Table 1). The highest total seed yield/ha was recorded at intra-row spacing of 30 cm; while, the lowest value was recorded at intra-row spacing of 90 cm (Table 9). Total seed yield/ha increased in closest intra-row spacing. This could be due to the fact that high population density per unit area attributed to the increase in total seed yield/ha. Contrasting result was reported by Aluko et al. (2011) on Kenaf and Uzun et al. (2012) on canola who observed that intra-row spacing did not affect seed yield.

3.3.10. Harvest index (%)

Interaction of variety with intra-row spacing exerted a significant (P<0.05) effect on harvest index (Table 1). The highest harvest index was recorded at interaction of variety WG-Hibiscus-Sudan with intra-row spacing of 90 cm; while, the lowest value was recorded at interaction of variety WG-Hibiscus-Jamaica with intra-row spacing of 30 cm (Table 7). Harvest index increased at widest intra-row spacing due to high proportion of dry calyx production to above ground dry matter of the plant shoot.

Table 9
Effects variety, inter- and intra-row spacing on yield attributes of roselle varieties planted at Wondo Genet, in 2014 cropping season.

Treatments and statistics	NCPH	FCYPH (kg)	DCYPH (kg)	SYPH (t)
Variety				
WG-Hibiscus-Jamaica	3054187a	9258.6a	1019.76a	1.56a
WG-Hibiscus-Sudan	1496527b	4170.7b	458.80b	0.79b
Mean	2275357	6714.65	739.28	1.18
CD $_{0.05}$	493114	1141.5	149.27	0.27
Inter-RS (cm)				
60	2584845a	7817.4a	865.78a	1.30
90	1965869b	5611.8b	612.77b	1.05
Mean	2275357	6714.6	739.28	1.18
CD $_{0.05}$	493114	1141.5	149.27	ns
Intra-RS (cm)				
30	3091832a	8983.7a	1025.42a	1.61a
60	2247463b	6241.8b	671.78b	1.18b
90	1486775c	4918.4b	520.63b	0.73c
Mean	2275357	6714.6	739.28	1.17
CD $_{0.05}$	731544	1693.4	221.45	0.4
CV (%)	31.35	24.59	29.21	33.13

Means followed by the same letter in the same column are not significantly different at 5% probability level using Tukey's Studentized Range (HSD) Test. ns= non significant at 5 % probability level, RS= Row spacing, NCPH= Total number of capsules/ha, FCYPH= Total fresh calyx yield/ha, DCYPH= Total dry calyx yield/ha, SYPH= Seed yield/ha and CD= Critical difference.

4. Conclusion

The present study demonstrated that, the highest total fresh and dry calyx yield/hawere recorded when WG-Hibiscus-Jamaica and WG-Hibiscus-Sudan were planted at inter-row spacing of 60 cm and intra-row spacing of 30 cm. When planting WG-Hibiscus-Jamaica at inter-row spacing of 60 cm and intra-row spacing of 30 cm (60 cm x 30 cm) total fresh and dry calyx yield/ha increased by 54.85 and 61.16 %, respectively as compared to planting at inter-row spacing of 90 cm and intra-row spacing of 90 cm (90 cm x 90 cm). When planting WG-Hibiscus-Sudan at inter-row spacing of 60 cm and intra-row spacing of 30 cm (60 cm x 30 cm) total fresh and dry calyx yield/ha increased by 86.29 and 87.62 %, respectively as compared to planting at inter-row spacing of 90 cm and intra-row spacing of 90 cm (90 cm x 90 cm). Based on this result, 60 cm inter-row spacing with 30 cm intra-row spacing is highly recommended for the highest total fresh and dry calyx yield/ha at Wondo Genet and at a place where having similar agro-ecologies to Wondo Genet.

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