INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
15–673/2016/18–6–1219–1224
DOI: 10.17957/IJAB/15.0215
http://www.fspublishers.org

Full Length Article

Effect of Sowing Time and Plant Density on the Growth and Production of Roselle (*Hibiscus sabdariffa*)

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Abstract

Experiments were conducted to see the response of roselle to different sowing dates and plant spacing. Six different sowing dates (seed sown at 10 days intervals on 6th May, 16th May, 26th May, 5th June, 15th June and 25th June) were used as main plots and six different planting densities (2, 3, 5, 7, 11 and 18 plants m^{-2}) as sub plots. Results showed that plant height, stem diameter, number of leaves, number of calyces per plant, fresh weight of calyces per plant, dry weight of calyces per plant and calyces yield per ha was significantly affected by different sowing dates as well as planting densities. Maximum plant height (175 cm), stem diameter (3.1 cm), number of leaves per plant (636), number of calyces per plant (104), calyces fresh (206 g) and dry (21.7 g) weight $plant^{-1}$, and calyces yield per ha (1427 kg) was recorded for the plants sown on 6th May, while these traits decreased with delayed sowing. For plant densities, the tallest plants (155 cm) with maximum calyces yield per ha (2496 kg) were observed at the highest density of 18 plants m^{-2}, though the per plant stem diameter (2.9 cm), number of leaves (653), number of calyces (99), calyces fresh (205 g) and dry (24.9 g) weight were higher at the lowest density of 2 plants m^{-2}. It was concluded that 6th May sowing and 18 plants m^{-2} planting density produced the highest yield per ha in roselle crop.

Keywords: *Hibiscus sabdariffa*; Plant density; Roselle; Sowing dates

Introduction

Roselle (*Hibiscus sabdariffa* L.) belongs to family Malvaceae. The crop is grown mainly in traditional farming system, mostly under rain fed conditions in many tropical and subtropical countries (Cobley, 1975). Its origin is West Africa, from where it was carried to India and other parts of Asia, and by slave trade to Central America and the United State of America (Mordock, 1959). The species *H. sabdariffa* was probably brought to the western hemisphere by slaves from Africa and was used in Jamica as early as 1707 (Crane, 1949). Roselle is a long day plant and is grown successively at temperature of 25 to 35°C or even higher. The plant grows well in most soils especially the well-drained soils. It can tolerate poor soils as well and is often grown as a supplementary rather than primary crop (Hacket and Carolene, 1982).

Roselle has many industrial, medicinal and domestic uses. It is used as a beverage, where the dried calyces are soaked in water to prepare a colorful and tasty cold drink. Traditionally, the product has been used for medicinal purposes, such as relief of sour throat and for healing wounds as an anti-septic (Ochani and Mello, 2009). Leaves of roselle are consumed green like vegetable and salad and the stem is used as a source of pulp in paper industry in many parts of the world. Seeds are used as poultry feed and as an aphrodisiac coffee substitute (Mahadevan *et al.*, 2009).

Roselle parts such as leaves, fruits, seeds and roots are used in different type of foods. Fresh calyces are used in the preparation of jam, jelly, juice, syrup, pudding, wine, cakes and ice cream for color and flavor. Calyces are dried, brewed and used in spices, tea, and also used for making pies, tarts, sauces, and other desserts. The calyces have pectin, which forms firm vegetarian jelly. The seeds are used in soups and sauces after roasting and powdering. The roasted seeds can also be used for making coffee. The young roots of roselle are edible and fibrous (Yadong, 2012). Extracts of roselle calyces are used for liver diseases, fever and high blood pressure. The calyx extracts are found to have strong *in vitro* and *in vivo* antioxidant activity (Ali *et al.*, 2005).

Roselle is an ideal crop for developing countries as it is in favorable market demand. It can be easily grown due to its drought tolerance but is not easy to be harvested mechanically, and need labor to process. Demand of roselle has increased for the last few decades. Presently approximately 15,000 metric tons is exported for international trade each year. Sudan produces the world's

To cite this paper: Khattak, A.M., M. Sajid, H.Z. Sarwar, A. Rab, M. Ahmad and M.A. Khan, 2016. Effect of sowing time and plant density on the growth and production of roselle (*Hibiscus sabdariffa*). *Int. J. Agric. Biol.*, 18: 1219–1224

best roselle but the quantity is low. Major producers of roselle are China and Thailand, which control a huge level of the world supply. Thailand production is large with a superior in quality, while product of China is not reliable due to poor quality control practices. Major importing countries of roselle are Germany and the United States (Plotto, 2004).

Roselle is often grown in tropical and subtropical regions. Pakistan has diverse agro-climatic conditions, which make it suitable for cultivation of a number of plants. With the increasing demand of food and alternate medicine, research is mostly focused on searching new crops. There is an enormous potential for roselle due to its medicinal, nutritional and economic importance. No scientific research is reported to have been done on the adaptation and properties of roselle in Pakistan. There was an intense need to study and develop the production technology for cultivation of roselle in Pakistan. The present work is part of the series of experiments carried out for the adaptation of roselle in this region.

Materials and Methods

Experimental Material and Treatments

An experiment was conducted to find out the best sowing time and plant spacing for roselle yield and production at the experimental nursery of Department of Horticulture, the University of Agriculture Peshawar in 2012. The experiment was repeated in the same environment in 2013. The experiments were laid out in two factor randomized complete block design (RCBD) with split plot arrangements. Six different sowing dates (6^{th} May, 16^{th} May, 26^{th} May, 5^{th} June, 15^{th} June, 25^{th} June, 2012 and 2013) were used as main plots, while six different planting densities (2, 3, 5, 7, 11 and 18 plants m^{-2}) were applied as sub plots.

Soil samples were taken from the experimental field to know its physico-chemical properties. The soil texture was silty clay loam with 54.4% silt, 31.4% clay, 15.7% sand and 0.80% organic matter. It also had 0.08 mg kg^{-1} nitrogen, 5.75 mg kg^{-1} phosphorus, 16.5% $CaCO_3$ with 7.8 pH and 0.15 d Sm^{-1} electrical conductivity (EC). The field was ploughed and manure was applied at the rate of 20 ton ha^{-1}. Before sowing half dose of nitrogen (40 kg ha^{-1}), and full doses of phosphorus (100 kg ha^{-1} P_2O_5 as triple super phosphate) and potash (50 kg ha^{-1} as potassium sulfate) were applied. The remaining half dose of nitrogen was applied fifteen days after germination. All crop management practices such as weeding, hoeing and irrigation were carried out uniformly to all the treatments according to the needs. The crop was sown in May and harvested in October. The average maximum and minimum temperatures during the course of the experiments were 35 and 24°C respectively. Similarly the average high and low relative humidity for the same period was 76 and 43%, respectively.

Data Collection and Statistical Analysis

Roselle seeds (acquired from Sudan) were sown on six different dates with 10 days intervals. Data were recorded for different variables such plant height (cm), stem diameter (cm), number of leaves per plant, number of calyces per plant, calyces fresh and dry weight per plant and calyces yield per ha. Plant height was measured from the base to apex for five randomly selected plants from each treatment. Stem diameter was taken with vernier caliper for five randomly selected plants from each treatment. The number of leaves and calyces was taken as the average of five randomly selected plants from each treatment. At maturity, calyces were removed from five randomly selected plants and their fresh weight was taken immediately. For dry weight, the calyces were kept in oven set at 70°C for 72 h. For calyces yield, the weight of dried calyces produced per plot was taken and converted to production per ha (kg). All the data taken were subjected to analyses of variance (2 factor) or linear regression analysis. MSTATC software (Michigan State University, USA) was used for computing analysis of variance and least significant difference (LSD) tests, and MS Excel for regression analysis.

Results

The main effects of sowing dates and plant densities along with their respective LSD values are summarized into Table 1. The results acquired are presented and discussed in the following lines.

Plant Height

Plant height was significantly ($P \leq 0.001$) affected both in case of sowing dates and plant densities. Maximum plant height was observed at the earliest sowing (6^{th} May), while minimum plant height was recorded in plants sown on 25^{th} June. In case of planting density, the tallest plants were recorded at 18 plants m^{-2} density, whereas the shortest plants were observed at a density of 2 plants m^{-2}.

Stem Diameter

For the different sowing times, maximum stem diameter was recorded in roselle plants sown on 6^{th} May, and 16^{th} May. The stem diameter decreased with delay in sowing and the lowest stem diameter resulted for the crop sown on 25^{th} June. In case of planting density, the highest density (18 plants m^{-2}) produced the thinnest stems. The stem thickness increased with the decrease in planting density and plant grown at the lowest density (2 plants m^{-2}) produced the thickest stems.

A regression analysis of the effect of plant density on stem diameter also showed a significant ($P \leq 0.01$) decrease in stem diameter ($y = 2.85 – 0.059x$; $R^2 = 0.90$) with the increase in plant density (Fig. 1) confirming the typical shade avoidance response.

Table 1: The effects of sowing dates and plant spacing on the growth and yield of Roselle

Sowing date	Plant height (cm)	Stem diameter (cm)	No of leaves	No of calyces	Calyces fresh wt. (g)	Calyces dry wt. (g)	Calyces yield (kg ha^{-1})
			Sowing Dates				
6th May	175 a	3.1 a	636 a	104 a	206 a	21.7 a	1427 a
16th May	167 b	3.1 a	619 b	102 a	199 b	19.8 b	1318 ab
26th May	158 c	2.4 b	619 b	91 b	197 b	19.2 b	1284 b
5th Jun	137 d	2.3 b	506 c	82 c	189 c	16.7 c	1066 c
15th Jun	118 e	1.8 c	498 c	70 d	165 d	19.4 b	1276 b
25th Jun	88 f	1.7 c	401 d	65 e	152 e	15.6 d	1019 c
LSD	1.22	0.13	11	2.32	3.6	1.1	112.8
			Plant Density (plants m^{-2})				
2	124 f	2.9 a	653 a	99 a	205 a	24.9 a	596 f
3	132 e	2.7 b	604 b	93 b	197 b	22.5 b	698 e
5	138 d	2.5 c	557 c	89 c	188 c	19.6 c	902 d
7	144 c	2.3 d	517 d	81 d	179 d	17.1 d	1179 c
11	150 b	2.1 e	485 e	77 e	169 e	14.2 e	1520 b
18	155 a	1.9 f	463 f	74 f	169 e	14.1 e	2496 a
LSD	1.1	1.1	9	2.38	4.5	1.4	101.7
Interactions	NS	*	**	*	NS	NS	NS

Means followed by different letters are significantly different at P≤0.01, LSD = Least significance difference, * = significant at P≤0.05, ** = significant at P≤0.01, NS = Non-significant

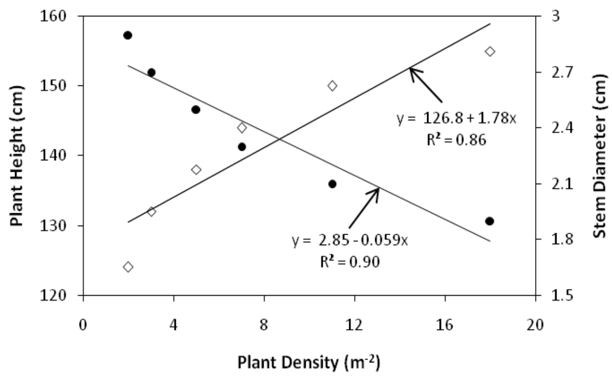

Fig. 1: The effect of plant density on the plant height (◊) and stem diameter (●) of Roselle

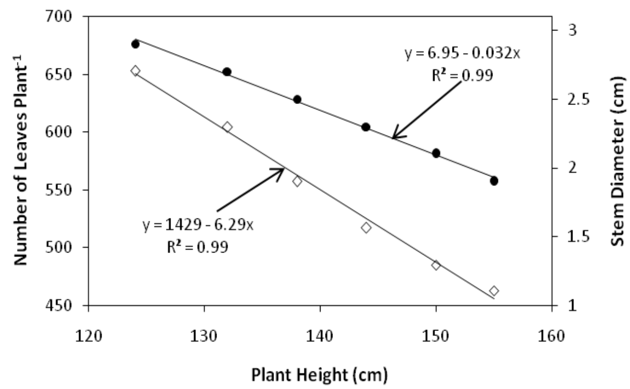

Fig. 2: Roselle plant height plotted against the number of leaves per plant (◊) and stem diameter (●)

Number of Leaves per Plant

In case of sowing times, maximum number of leaves was obtained from the plants sown on 6th May. The leaf number decreased with delayed sowing such that minimum number of leaves was recorded in plants sown on 25th June. As for the planting density, the highest number of leaves was obtained from plants grown at 2 plants m^{-2} density, while increasing the plant density decreased the number of leaves and minimum leaves were observed at planting density of 18 plants m^{-2}.

The linear regression analysis (Fig. 3), showed that leaf number significantly ($P \leq 0.05$) decreased with the increase in plant density ($y = 629.7 - 10.86x$; $R^2 = 0.80$) confirming previous studies (see discussion).

Number of Calyces per Plant

Calyx is the main part of the plant consumed commercially as beverages, spices and medicine, though other plant parts such as leaves, stems and roots are also used for different purposes. The number of calyces per plant of roselle was also significantly ($P \leq 0.001$) affected by different sowing dates and planting density (Table 1). The highest number of calyces was obtained from plants sown on 6th May, while the lowest number of calyces was recorded for the crop sown on 25th June. In case of planting density, maximum number of calyces was obtained from plants grown at 2 plants m^{-2} density, while minimum number of calyces was produced by plants grown at the density of 18 plants m^{-2}.

The linear regression analysis (Fig. 3) showed a significant ($P \leq 0.05$) decrease in number of calyces per plant with the increase in planting density ($y = 96.82 - 1.48x$; $R^2 = 0.82$).

Calyces Fresh Weight per Plant

Maximum calyces fresh weight per plant was obtained from plants sown on 6th May, while the fresh weight decreased with the delay in sowing time and minimum fresh calyces weight per plant was produced by the plants sown on 25th June. In case of planting density, maximum fresh calyx weight per plant was obtained at the lowest plant density i.e. 2 plants m^{-2}. The calyces fresh weight per plant decreased with the increase in plant density and minimum calyces fresh weight per plant was produced by the plants grown at higher densities of 11 and 18 plants m^{-2}.

Calyces Dry Weight per Plant

The dry weights followed a similar pattern like calyces fresh weight. Maximum calyces dry weight per plant was recorded at the earliest sowing date (6th May). Delaying the sowing time decreased the weight and minimum calyces dry weight per plant was recorded for plants sown on 25th June. For the plant densities, maximum calyces dry weight per plant was produced by the plants grown at the lowest density (2 plants m^{-2}). The weight decreased with increasing plant densities and minimum calyces dry weight per plant was obtained at the highest plant density (18 plants m^{-2}). Regression analysis of the data (Fig. 4) also showed a significant ($P \leq 0.05$) decrease in calyces dry weight $plant^{-1}$ with the increase in planting density ($y = 23.72 – 0.65x$; $R^2 = 0.78$).

Calyces Yield

Among sowing dates, maximum calyces yield was obtained from the plants sown on 6th May. The yield decreased as the sowing was delayed, where the plants sown on 25th June resulted in minimum calyces yield. Among the different planting densities, maximum calyces yield per ha was obtained from plants grown at the highest density (18 plants m^{-2}). The calyces yield per ha decreased with decreasing densities with the lowest density (2 plants m^{-2}) producing minimum calyces yield (596 kg ha^{-1}). The regression model of the calyces yield per ha depicts the best fit to the data (Fig. 4). There was a significant ($P \leq 0.001$) linear increase in the yield per ha of roselle with the increase in plant density ($y = 332.6 + 117.2x$; $R^2 = 0.99$).

Discussion

The probable reason for the differences in plant height due to sowing dates is that early sown roselle plants had a longer period for vegetative growth, which produced taller plants. Selim *et al.* (1993) and Lamido (1998) reported that the plant height of roselle was maximum when sown during the first week of May in Sudan.

The variation in plant height due to the planting density is indicative of a classical shade avoidance response, where plant height tends to increase with higher densities at the expense of other growth characters such as stem diameter, leaf size and number, and even flowering. This is due to the difference in red (R): far red (FR) ratio perceived by the plants grown at different densities.

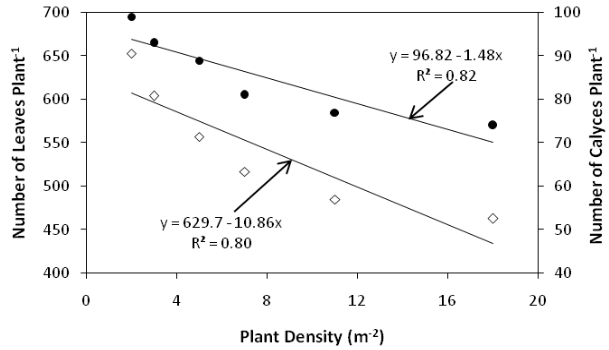

Fig. 3: The effect of plant density on the number of leaves per plant (◊) and number of calyces per plant (●) of Roselle (*Hibiscus sabdariffa*)

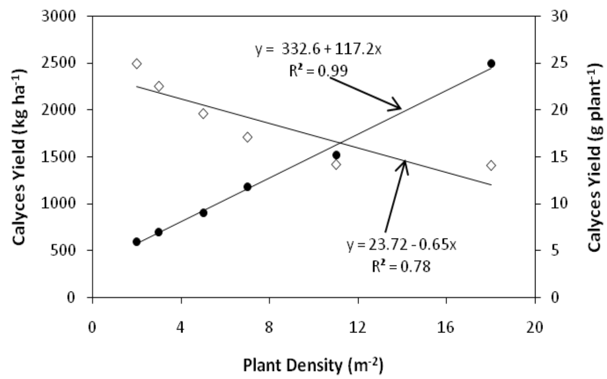

Fig. 4: The effect of plant density on calyces yield per ha (●) and calyces yield per plant (◊) of Roselle

The effect of R:FR ratio on phytochrome photoequilibrium and hence the plant height is well documented (Smith, 1982; Brown, 1984; Smith, 1995; Smith and Whitelam, 1997; Khattak and Pearson, 1997, 2005, 2006; Khattak *et al.*, 2004, 2011; Khattak and Salam, 2007). As the plant leaves are transparent to FR radiation (700–800 nm wavelength) and partially filter the visible radiation (light i.e., 400–700 nm wavelength) including red light (600–700 nm wavelength), the results in reducing the R:FR ratio, thereby increasing the plant height. McLaren and Smith (1978) and Shalaby and Razin (1989), observed that red light interception caused low R:FR and consequently increased plant height.

To understand this phenomenon for roselle plant, the plant height was plotted against the plant density (Fig. 1). The regression analysis showed a substantial ($P \leq 0.01$) increase in plant height ($y = 126.8 + 1.78x$; $R^2 = 0.86$) with the increase in density. To further elucidate the phytochrome response to the changing red far-red ratio due to different densities, the stem diameter and number of leaves were plotted against the plant height (Fig. 2). A significant decrease was observed for both the stem diameter ($y = 6.95 – 0.032x$; $R^2 = 0.99$; $P \leq 0.001$) and number of leaves ($y = 1429 – 6.29x$; $R^2 = 0.99$; $P \leq 0.001$)

with the increase in plant height. This shows a typical plant response towards the changing densities and neighbor detection. The plants develop a strategy to grow taller in order to capture more photosynthetic radiation at the expense of stems being thinner and leaves smaller and lesser (Smith, 1982).

Early sowing increased stem diameter, which might be due to longer period for vegetative growth in early sown crop. Selim *et al.* (1993) and Lamido (1998) observed that steam diameter of roselle decreased with increasing plant density. The variation in stem diameter might be due to the effect of planting density on the inter-plants competition for nutrients, lights and other important growth factors, which cause variation in stem diameter (Brown, 1984). Shalaby and Razin (1989) also observed maximum stem diameter at lowest plant density at 70 cm spacing.

The highest number of leaves obtained from the early sowing dates can be attributed to the longer growth period and the favorable environmental conditions, long hot days in this case. Similarly, the variation in number of leaves due to plant densities might be due to the increase of inter-plant competition with the increasing planting density. This caused lower crop growth and etiolation due to shading effect, which led to a decrease in the number of leaves (Ameri *et al*., 2008). Amjad *et al.* (2001) also observed maximum number of leaves for plants grown at the lowest planting density of 111000 plants ha^{-1}. It is obvious that if plant density affects growth parameters such as leaves, which are the main source of producing photosynthates, the calyces production will be affected as a consequence.

The effect of sowing dates on flowering might be due to the longer duration of growth period, which resulted in greater canopy and more assimilates available for the plant to produce more flowers per plant. The variation in number of calyces per plant due to the planting densities can be attributed to the fact that at higher planting densities the competition for food, water and light increases, which results in lesser number of calyces compared to those produced by plants grown at lower densities.

Calyces weight increase in early sown plants might be the results of better dry matter accumulation for vegetative and hence reproductive growth. Thus, the increase in calyces weight per plant was due to more assimilates partitioned into the fruits (Ameri *et al.*, 2008). Likewise, the increase in weight of calyces at lower densities might be due to the fact that there was less competition for nutrients and other factors among the plants. As mentioned earlier, plant densities affected the different growth and development parameters of roselle plants. This affected the calyces yield per plant as well. Similar results were shown by Mir *et al.* (2011), who observed that cultivation dates and planting densities had significant effects on morphological characteristics and increasing plant density caused significant reduction in roselle yield per plant. Futuless *et al.*, 2010 also observed a decrease in calyces yield with delayed sowing time.

There was a substantial effect of both sowing time and planting density on the calyces yield per ha. A significant linear increase in the yield per ha of roselle was observed with the increase in plant density. This is opposite to the calyces yield per plant data, where the yield decreases with the increase in plant density. However, it should be noted that though the yield per plant decreases with higher densities, there are more plants per unit area, which comprise and boost the total roselle yield per ha. The total calyces yield per ha increased linearly with the increase plant densities right up to the maximum density (18 plants m^{-2}). No decline in yield of roselle was observed up to that point in the present study. However, there must be a decline in the yield at a certain point beyond this (18 plants m^{-2}), which needs further investigation.

Conclusion

Different sowing dates and planting densities had significant effects on the yield and yield related traits of roselle. Sowing the crop on 6th May produced maximum growth and yield. Though the lowest plant density (2 plants m^{-2}) produced more leaves and calyces per plant, the production per ha (per unit area) was the lowest. The highest planting density (18 plants m^{-2}) was the best as it provided the highest per ha calyces yield and other traits.

Acknowledgements

The authors acknowledge and appreciate Mr Zubair Qureshi, Learning and Development Coordinator Sudan (RedR UK) for providing Roselle seed from Sudan for the experiment.

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(Received 07 June 2015; Accepted 27 July 2016)