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Growth and Yield of Roselle as Influenced by Farmyard Manure and Inorganic Fertilizers

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Abstract: Productivity of the crop is limited by many constraints; among others, soil nutrient is the main factor. Hence, a field experiment was conducted during 2017 cropping season to evaluate the combined effects of inorganic (NP) fertilizer and farmyard manure (FYM) on growth, calyx yield and yield components of roselle at Hawassa Green Mark Herb research station, south Ethiopia. The treatments consisted of four rates of inorganic (0/0, 23/10, 46/20 and 69/30 kg NP ha^{-1}) and four levels of FYM (0, 5, 10 and 15 t ha^{-1}). The experiment was laid out in a randomized complete block design in a factorial arrangement and replicated three times. The results showed that application of NP fertilizer in combination with FYM significantly ($P<0.05$) influenced plant height, number of branches per plant, stem diameter, leaf area index, number of pods per plant, fresh and dry calyx yield per hectare and seed yield per hectare except days to emergence, days to 50% flowering and days to maturity. The highest fresh calyx yield (11.18 t ha^{-1}) and dry calyx yield (1.38 t ha^{-1}) were recorded for 69/30 kg NP ha^{-1} plus 15 t FYM ha^{-1}. The lowest fresh calyx yield (4.31 t ha^{-1}) and dry calyx yield (0.529 t ha^{-1}) were obtained from the control treatment. In conclusion, the results of this study indicated that applying 69/30 kg NP ha^{-1} in combination with 15 t farmyard manure ha^{-1} brought about maximum calyx yield and thus, can be recommended for the production of roselle in the study area.

Key words: Calyx · NP fertilizer · Plant height · Seed yield · Soil nutrient · Stem diameter

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a botanical species of the family Malvaceae. The plant is probably native to tropical Central and West Africa and it is mainly cultivated in tropical and subtropical regions of the world for its attractive edible calyces [1]. It is known as '*Karkade'* in Ethiopia. The economic part of the plant is the fleshy calyx surrounding the fruit (capsules). The plant, normally grown as an annual plant, is 0.5 to 2.4 meters in height. It has a bushy shape with a dense canopy of dark green leaves [2].

Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns [3]. A balanced application of both organic and inorganic fertilizers with biofertilizers appears to be an ideal proposition to meet nutrient requirements for most of the horticultural crops like roselle [4]. Basri *et al*. [5] reported that growth performance of *Hibiscus* was significantly influenced due to different application rate or combination of organic and inorganic fertilizers. Effect of nitrogen and phosphorus on plant height, fresh sepals and dry weight of sepals were studied by Keykha *et al*. [6] and the highest 150 kg N and 100 kg of P per hectare treatments showed a significant difference from the lowest application. Okosun [7] reported that calyx yield of roselle showed significant to the rates of nitrogen and phosphorus; the highest yield per hectare was 669 kg ha^{-1} at 60 kg N ha^{-1} and 720 kg ha^{-1} at 30 kg P ha^{-1}. Gendy [8] reported that application of cattle manure fertilizer tended to a significant increase in fruit number/plant compared to control treatment. The response of the dry weight of sepals/plant and dry weight of sepals/calyx yield, to cattle manure fertilization behaved similarly as that of the fruits number.

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In Ethiopia, the calyx of roselle is needed by supermarkets and small processing companies for the preparation of herbal tea. The crop is produced by smallholder farmers and supplied for domestic consumption [9]. Most of the areas under cultivation have nutrient deficiency mainly of nitrogen and phosphorus. Productivity of this crop is not attractive under poor soil fertility status, hence, the producers are not happy to expand the area for production of the crop. Even though the crop is cultivated in the study area, there is no any information concerning integrated nutrient management to increase its yield and get better profit which can increase the income of the farmers by supplying high and quality calyx to the local and international markets. As a best opportunity, there is a good access to get locally available organic fertilizers like farmyard manure which can increase yield of the plant through integration with inorganic fertilizers. Therefore, the objective of this study was to determine the optimum rate of inorganic fertilizers and farmyard manure that promote growth and calyx yield of roselle.

MATERIALS AND METHODS

Description of the Study Site: The experiment was conducted at Hawassa Green Mark Herb research station during 2017/18 cropping season. The station is located at 7°05' North latitude and 39°29' East longitude at an altitude of 1652m a.s.l in the Southern, Nations, Nationalities and Peoples' Region (SNNPR). It receives total annual rainfall of 964 mm with minimum and maximum temperatures of 13°C and 27°C, respectively. Soil textural class of the experimental area was sandy loam with a pH of 7.84.

Experimental Materials: Roselle variety 'WG-Hibiscus-Sudan', which was registered by Wondo Genet Agricultural Research Center (WGARC) was used for this particular study as a test crop. It is well adapted to areas with an altitude of 1600-1800m a.s.l and day and night temperature of 26-29°C and 12-14 °C, respectively. Urea (46% N) and triple superphosphate (TSP) (46% P_2O_5) were used as sources of nitrogen and phosphorus, respectively. Locally available and partially decomposed farmyard manure (FYM) was used as a source of organic input.

Treatments and Experimental Design: The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement of 4x4 treatments replicated three times. The treatments consisted of four levels of nitrogen and phosphorus (0/0, 23/10, 46/20 and 69/30 kg ha^{-1}) and four levels of farmyard manure (FYM) (0, 5, 10 and 15t ha^{-1}). Three blocks were prepared, in which all the 16 treatment combinations were randomly assigned to the experimental units. Pathways between blocks and plots were maintained at 1.5m and 1m spacing, respectively. Each plot had a size of 3.6mx1.8m (6.48 m^2) accommodating six rows with an inter and intra-row spacing of 60 and 30cm, respectively [10]. Each row and plot had 6 and 36 plants, respectively and only the central four rows were used for data collection.

Incorporation of Farmyard manure into the soil by spreading in the plots was done 30 days before sowing on dry weight basis [11]. Plant populations were maintained by sowing three seeds per hill and thinning was done 15 days after sowing to obtain one plant per spot. A full dose of TSP fertilizer was applied at the time of sowing, while Urea was applied in two splits (1/3 during sowing and the remaining 2/3 was applied before flower initiation. Weeding and other cultural practices were done as required uniformly for all treatments.

Soil sampling and Analysis: Acomposite soil sample was collected from 0-30cm depth following the standard soil sampling procedures before application of the treatments. Uniformly slices and adequate volumes of soil was obtained in each sub-sample by vertical insertion of an auger. Then the collected composite soil sample was air dried and grounded to pass through a 2 mm sieve, except for the analysis of organic carbon and nitrogen, where the sample was passed through a 0.5 mm sieve. The working sample was obtained from the submitted sample and analyzed for selected physicochemical properties, such as texture, pH, organic carbon, total N, available phosphorus and cation exchange capacity (CEC) using standard laboratory procedures. Sample was also taken from farmyard manure and subjected to chemical analysis using the same procedures before incorporated into the soil. All parameters were done as described by Food and Agriculture Organization of the United Nations [12] in its bulletin with guide to laboratory establishment for plant nutrient analysis.

Data Collection and Measurements: Plant growth and yield-related traits were recorded from five sample plants randomly selected from the central rows in each plot, leaving aside, plant from the border rows and those at both edges of each row.

Phenological Parameters

Days to 50% Flowering: Days to flowering were determined as the number of days from emergence to the period when 50% of the plants in each plot produce their first flower. Days to maturity was taken as the number of days from emergence to the period when the plants in a plot became yellow, tending to shed their lower leaves and the lowest capsules on the stem were about to split or open.

Growth Parameters: Plant height (cm) was measured from the soil level to the apex of the main stem using a measuring tape at the maturity stage. It was measured using five plants and the average value for each plot was taken for data analysis. Number of primary branches of five plants within the net plot was counted. The average was recorded as a mean number of branches per plant for data analysis.

Yield and Yield Components: Number of pods per plant; five plants randomly selected from the net plot were used and all pods on a plant were counted at plant maturity stage and the average was used for data analysis. Fresh calyx yield per hectare (t); The Calyces were peeled off from the capsules/pods of a plant manually by hand after the flowers were dropped, but before the seed pods were dried and opened. Then the calyces were weighed by using an electronic sensitive balance. The average of five plants was taken as fresh calyx yield per plant and then converted to t/ha. Dry calyx yield per hectare (t): The calyces of five plants were peeled off from the capsules manually by hand. The calyces were dried under shade to a constant weight. Then average calyces yield per plant was determined using an electronic sensitive balance and converted into t/ha. Seed yield per hectare (t): Seed yield from the net plot was dried in sun and adjusted to 10% moisture content and the average weight of five plants was taken using electronic sensitive balance and converted into t/ha.

Data Analysis: For each measured response variable analysis of variance (ANOVA) and mean separation procedure was undertaken. After fitting analysis of variance (ANOVA) model for those significant interactions or main effects, mean separation was done using Duncan's New Multiple Range Test (DNMRT at 5 % probability level. Pearson correlation analysis for different characters was also carried out to observe associations between characters. All the statistical analysis was carried out using Statistical Analysis System (SAS) software version 9.3 [13].

RESULTS AND DISCUSSION

Phenological and Growth Parameters: The application of NP fertilizer and FYM significantly affected both days to 50% flowering and days to maturity of roselle. Application of 69/30 kg ha^{-1} of NP or 15 t ha^{-1} of FYM increased days to 50% flowering by 4.5% and 9.8%, respectively compared to the control plot. Also, number of days required for maturity date was increased by 8.7% and 3.8% over the control at application of 15 t FYM ha^{-1} or 69/30 kg NP ha^{-1}, respectively (Table 1).

Thus, plots treated with no organic and inorganic fertilization took shorter days to flower and mature than did fertilized plots. As the levels of NP and FYM increased days to flowering and maturity were also prolonged. This might be because of more efficient use of nutrients by plants for extended and various vegetative growth. Similarly, Michael [14] indicated that application of N fertilizer is beneficial to vegetative growth and prolongs flowering.

Plant Height: There was significant ($P \leq 0.05$) interaction of inorganic (NP) fertilizers and farmyard manure for plant height of roselle. The combined application of organic (FYM) and inorganic (NP) fertilizer produced plants that are taller than what was observed in the control plot. Application of 69/30 kg ha^{-1} of NP plus 15 t ha^{-1} of FYM resulted in tallest roselle plants (194.33 cm) and the shortest roselle plants were observed for the control (120.40 cm) treatment (Table 2). The increase in plant height due to combined application of higher rates of NP and FYM could be attributed to an adequate supply of nutrients that enhanced cell division and cell enlargement, resulting in increased extension growth and, thus, plant height. The beneficial effect of application of farmyard manures along with inorganic fertilizers was reflected by enhanced growth of the plant. The increase in extension growth may also be due to readily available N from inorganic fertilizers, which would be responsible for promoting plant height [15]. Moreover, farmyard manures are also significant sources of major and micronutrients which are much needed by the plants for normal growth and development [16].

Number of Branches per Plant: Number of branches per plant was significantly ($P \leq 0.05$) influenced by the interaction of NP and farmyard manure. The results showed that plots treated with 69/30 kg ha^{-1} of NP plus 10 t ha^{-1} of FYM exhibited the highest mean number of branches per plant (13.83), which was superior to all other treatments. While the lowest number of (5.2) branches

Table 1: Effect of inorganic (NP) fertilizer and farmyard manure on days to 50% flowering and days to maturity of Roselle at Hawassa during 2017 cropping season.

Treatments	Days to 50% flowering	Days to maturity
0	91.33^{b}	122.67^{b}
23/10	90.25^{b}	121.67^{b}
46/20	95.24^{a}	127.05^{a}
69/30	96.18^{a}	128.09^{a}
$CR_{0.05}$	1.73	2.32
0	87.25^{d}	117.92^{d}
5	92.16^{c}	124.33^{c}
10	95.67^{b}	127.25^{b}
15	97.83^{a}	130.33^{a}
$CR_{0.05}$	1.73	2.32
CV (%)	2.07	2.11

CR= critical range; CV= coefficient of variation; NP= nitrogen and phosphorus; FYM= farmyard manure; cm= centimeter. Figures followed by the same letters within a column for a given treatment level are not significantly different at P= 0.05.

Table 2: Interaction between inorganic (NP) fertilizer and farmyard manure on plant height (PH) and number of branches per plant (NBPP) of roselle plants at Hawassa.

NP (kg ha^{-1})	FYM (t ha^{-1})	PH(cm)	NBPP
0	0	120.40^{f}	5.2^{i}
	5	127.93^{ef}	6.27^{hi}
	10	132.00^{e}	7.13^{fgh}
	15	135.93^{de}	7.56^{efgh}
23/10	0	129.73^{ef}	6.53^{gh}
	5	132.8^{e}	7.87^{defg}
	10	136.03^{de}	8.40^{def}
	15	144.07^{cd}	9.13^{d}
46/20	0	150.6^{c}	8.93^{de}
	5	164.67^{b}	12.13^{bc}
	10	171.67^{b}	12.80^{abc}
	15	185.60^{a}	13.36^{ab}
69/30	0	163.73^{b}	11.33^{c}
	5	186.73^{a}	13.27^{ab}
	10	193.00^{a}	13.83^{a}
	15	194.33^{a}	13.26^{ab}
$CR_{0.05}$		9.60	1.63
CV(%)		3.73	9.98

CR= critical range; CV= coefficient of variation; NP= nitrogen and phosphorus; FYM= farmyard manure; cm= centimeter. Figures followed by the same letters within a column for a given treatment level are not significantly different at $P \leq 0.05$.

plant^{-1} was obtained from the control treatment (Table 2). This might be attributed to increased supplies of numerous plant nutrients from farmyard manure and NP fertilizer to the plants, which might have promoted the growth of lateral shoots. This result is in agreement with the findings of Akanbi *et al*. [17], who reported that all fertilized roselle plants progressively increased their number of main branches from three for the control treatment to 8-10 branches per plant. According to Arsham [18], application of 150 and 100 kg ha^{-1} NPK) and 20 t ha^{-1} of ostrich manure showed high branch number (4.66 branches) compared to the control treatment (1.66 branches).

Yield and Yield Components

Number of Pods per Plant: The combined effect of inorganic (NP) and FYM was significant ($P < 0.05$) for number of pods per plant. Among the interactions, application of 69/30 kg ha^{-1} of NP plus 15 t ha^{-1} of FYM gave the maximum number of pods per plant (90.11), but statistically at par with plots that received 46/20 kg ha^{-1} NP plus 15 t ha^{-1} FYM, 69/30 kg ha^{-1} NP plus 5 t ha^{-1} FYM and 69/30 kg ha^{-1} NP plus 10 t ha^{-1} FYM. The lowest mean number of pods per plant (49.22) was obtained from the control plot (Table 3). It was observed that as the rate of NP fertilizers and farmyard manure increased; a number of pods per plant also increased. This might be due to release of sufficient amount of nutrients from NP and FYM which enhances vigorous growth of the plant with greater leaf area and dry matter production, contributing to production of more number of pods per plant as nutrient from NP and FYM improve vegetative growth, synthesis and translocation of photosynthesis from the sources to the sink and thus, significantly increase number of pods per plant. A similar work has been reported by Akanbi *et al*. [17], where a combination of 5 t ha^{-1} of cassava peel compost (CPC) and 150 kg ha^{-1} NPK was found to be adequate for optimum growth and pod yield of roselle.

Fresh Calyx Yield per Hectare: The analysis of variance showed that there was highly significant ($P < 0.01$) interaction between NP and FYM treatments. The result of present study indicated that fertilization significantly increased fresh calyx yield of roselle over the control. The highest mean fresh calyx yield per hectare (11.18 t) was obtained in roselle plants received 69/30 kg ha^{-1} of NP combined with 15 t ha^{-1} of FYM. However, application of 46/20 kg ha^{-1} of NP plus 15 t ha^{-1} of FYM, 69/30 kg ha^{-1} of NP plus 5 t ha^{-1} of FYM and 69/30 kg ha^{-1} of NP plus 10 t ha^{-1} of FYM didn't show statistically significant difference from the maximum value (Table 3). Higher yield in response to farmyard manures could be ascribed to improvement in physical and biological properties of the soil, which might have resulted in better supply of nutrients to plants leading to enhanced crop growth and yield. The increase in fresh calyx yield might also be due to the supply of an adequate amount of nutrients in the right proportion that positively influence yield in roselle.

Table 3: Number of pods per plant (NPPP), fresh calyx yield per hectare (FCYPH), dry calyx yield per hectare (DCYPH) and seed yield per hectare (SYPH)of roselle as influenced by interaction of NP fertilizers and FYM at Hawassa

NP (kg ha^{-1})	FYM (t ha^{-1})	NPPP	FCYPH (t)	DCYPH (t)	SYPH (t)
0	0	49.22^{g}	4.31^{j}	0.529^{i}	0.99^{h}
	5	51.95^{fg}	4.62^{ij}	0.583^{hi}	1.19^{gh}
	10	53.89^{fg}	5.07^{hij}	0.627^{ghi}	1.28^{efg}
	15	55.91^{ef}	5.36^{ghi}	0.684^{gh}	1.15^{gh}
23/10	0	55.56^{ef}	5.60^{fgh}	0.709^{fgh}	1.25^{fg}
	5	60.57^{de}	6.17^{efg}	0.754^{efg}	1.30^{efg}
	10	59.83^{de}	6.39^{ef}	0.777^{ef}	$1.45d^{ef}$
	15	62.30^{d}	6.57^{e}	0.820^{ef}	1.53^{de}
46/20	0	65.00^{cd}	6.90^{e}	0.846^{e}	1.57^{cd}
	5	77.93^{b}	9.59^{c}	1.188^{cd}	1.94^{b}
	10	79.78^{b}	9.75^{bc}	1.231^{bc}	1.97^{b}
	15	86.97^{a}	10.47^{abc}	1.278^{abc}	2.40^{a}
69/30	0	70.54^{c}	8.37^{d}	1.056^{d}	1.82^{bc}
	5	87.25^{a}	10.63^{ab}	1.312^{abc}	2.33^{a}
	10	90.01^{a}	10.85^{a}	1.361^{ab}	2.43^{a}
	15	90.11^{a}	11.18^{a}	1.380^{a}	2.48^{a}
$CR_{0.05}$		5.90	0.89	0.13	0.25
CV(%)		5.16	7.00	9.01	8.94

CR= critical range; CV= coefficient of variation; NP= nitrogen and phosphorus; FYM= farmyard manure; cm= centimeter. Figures followed by the same letters within a column for a given treatment level are not significantly different at $P \leq 0.05$.

This could be the reason why plants nourished with the combined treatments performed better than others that received limited nutrients. Akanbi *et al*. [17] also reported that application of 5 t ha^{-1} cassava peel compost (CPC) with 150 kg ha^{-1} NPK seemed to contain sufficient amount of nutrients to increase the yield and irrespective of quantity, plants that received only compost performed poorer when compared with those which received only mineral fertilizer or combination of the two. Haruna *et al*. [19] have found that the application of 60 kg ha^{-1} of nitrogen fertilizer and 5 tons ha^{-1} of poultry manure significantly increased calyx yield and profitability of roselle. According to their report, fresh calyx yield increased from 2.64 t ha^{-1} to 9.96 t ha^{-1} as compared to unfertilized roselle plants.

Dry Calyx Yield per Hectare: The analysis of variance showed that there was significant ($P< 0.05$) interaction between applied the treatments (NP and FYM) for dry calyx yield per hectare of roselle. The highest dry calyx yield (1.38 t ha^{-1}) was obtained when 69/30 kg ha^{-1} of NP was integrated with 15 t ha^{-1} of FYM (Table 3). The lowest value (0.529 t ha^{-1}) was recorded for the control treatment. The increase in calyx yield of roselle as a result of combined application of NP and FYM may be attributed to an increase in photosynthetic area as a result of enhanced vegetative growth due to increased availability of N. High nutrient application also promotes high dry matter accumulation and translocation to the economic yield. As reported by Rao and Shaktawat [20] the increase in dry calyx yield due to integrated approach might be attributed to the favorable effect of organic manure (FYM) in the supply of additional nutrients through mineralization and improvement in physicochemical properties of the soil. The finding of the present study is also in line with the report of Oyewole and Mera [21], who observed that application of manure at 7.5 tons/ha or nitrogen at a rate of 75 kg N/ha gave the highest dry calyx yield of roselle. Increase in dry calyx yield might be due to the positive contribution of fertilizers to dry matter accumulation in plants. The stimulating effect of NP and organic manures on yield was also investigated by Radwan and Farahat [22] on kenaf plant. The report of Mera *et al*. [23], indicated that application of N and farmyard manure significantly influenced dry calyx yield over the control or unfertilized plots. According to these authors, application of 2.5 t ha^{-1} of farmyard manure and 50 kg ha^{-1} of N gave 380.2 kg ha^{-1} and 433.9 kg ha^{-1} of dry calyx yield, respectively.

Seed Yield per Hectare: The analysis of variance showed that the interaction of NP and FYM was significant ($P< 0.05$) for seed yield per hectare. The highest seed yield (2.48 t per ha) was recorded for the combination of 69/30 kg ha^{-1} of NP fertilizer plus 15 t ha^{-1} of FYM while the lowest value (0.99 t per ha) was obtained from the control plot (Table 3). The result indicated that there was an increasing trend of seed yield as the rate of fertilizer increased. Hence, application of 69/30 kg ha^{-1} of NP fertilizer plus 15 t ha^{-1} of FYM seemed to contain sufficient amount of nutrients. This could be the reason why roselle plants nourished with these treatment performed better than others did. It has been reported that, irrespective of quantity, plants that received only compost performed poorer when compared with those which received only mineral fertilizer or combination of the two, probably because of readily available nature of inorganic fertilizers than organic fertilizers which complementary effects. Similar observations were reported by Akanbi [24] for okra and by Stefano *et al.* [25] for tomato. The result of the present study were also in agreement with the findings of Sahoo and Panda [26], who reported higher seed yield (3269 kg ha^{-1}) of maize with the application of N, P_2O_5 and K_2O at the rate of 80, 40 and 40 kg along with FYM at a rate of 5 t ha^{-1} compared to the control (1323 kg ha^{-1}) and inorganic fertilizer applied plot (3036 kg ha^{-1}) alone.

CONCLUSION

The results obtained from this study indicated that application of inorganic fertilizers (NP) plus farmyard manure influenced growth, yield and yield components of roselle. The interaction of NP and farmyard manure significantly ($P \leq 0.05$) affected plant height, number of branches per plant, stem diameter, leaf area index, number of pods per plant, fresh calyx yield per hectare, dry calyx yield per hectare and seed yield per hectare. The highest and lowest mean values of plant height (194.33 cm and 120.40 cm), leaf area index (4.57 and 2.82), number of pods per plant (90.11 and 49.22), fresh calyx yield per hectare (11.18 t and 4.31 t), dry calyx yield per hectare (1.38 t and 0.529 t) and seed yield per hectare (2.48 t and 0.99 t) were recorded for 69/30 kg NP ha^{-1} plus15 t FYM ha^{-1} and the control treatment, respectively. Application of 69/30 kg NP ha^{-1} plus 10 t FYM ha^{-1} gave the highest number of branches (13.83) while the lowest value (5.2) was obtained from the control. Application of 46/20 kg NP ha^{-1} plus 5 t FYM ha^{-1} resulted in maximum stem diameter (1.71cm) while the thinnest stem (1.22cm) was observed for 23/10 kg NP ha^{-1} plus 5 t FYM ha^{-1} followed by the control. The results of the present study indicated that application of 69/30 kg NP ha^{-1} plus 15 t FYM ha^{-1} improved calyx yield of roselle through improving soil physical characteristics and soil nutrient availability resulting in better vegetative growth, yield components and, thereby, recommended for higher yield and benefit of the calyx in the study area.

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