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Determination of Optimum Farmyard Manure Rates for Growth, Yield and Yield Components of Roselle (*Hibiscus sabdariffa* L.)

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Abstract **– Organic fertilizer like farmyard manure is important to improve the yield and quality of roselle as well as soil structure. To test the effect of farmyard manure on growth and yield of roselle field experiment was conducted at Hawassa research station. The experiment was laid in RCBD design with four replications in which all the four levels of farmyard manure was equally distributed. The results showed that application of farmyard manure significantly influenced days to 50% flowering, days to maturity, plant height, stem diameter, leaf area index, number of pods per plant, fresh and dry calyx yield per hectare, seed yield per hectare and above ground dry biomass. The highest fresh calyx yield (5.36 t ha^{-1}) and dry calyx yield (0.68 t ha^{-1}) were recorded for 15 t farmyard manure ha^{-1}. The lowest fresh calyx yield (4.31 t ha^{-1}) and dry calyx yield (0.53 t ha^{-1}) were obtained from the control (0kg farmyard manure per hectare). In conclusion, the results of this study indicated that applying 15 t farmyard manure per hectare brought about maximum calyx yield and thus, can be recommended for the production of roselle in the study area. Multi location and multiyear trial should be conducted to come up with comprehensive recommendation.**

Keywords **– Calyx, Farmyard Manure, Growth, Roselle, Yield and Yield Components.**

I. 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 has a bushy shape with a dense canopy of dark green leaves. The color of the calyx plays an important role in determining the quality of the crop. The crimson red color is the characteristic and most popular and desirable color of Roselle, while other shades and colors exist, including white or greenish white color [2].

Increasing food production that is safe and nutritious is a global need. Also increasing yield is the most important agro-economic goal of farmers. For healthy growth and optimal yield, nutrients must be available to plants in a correct quantity, proportion and in a usable form at the right time and right place. To fulfill these requirements, chemical fertilizers and/or organic manures are needed. Because of its superior effect on plant growth and yields conventional NPK (Nitrogen, phosphorus, and potassium) fertilizers has been preferred by most of the plant growers. Nitrogen and Phosphorus are two major limiting nutrients for plant growth and yield. Nitrogen is needed for normal growth and the synthesis of proteins in plant [3]. Phosphorus is also essential in several biochemical that control photosynthesis, respiration, cell division, and many other plant growth and development processes [4].

Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns [5]. On the other hand, increasing costs of chemical inputs have left farmers helpless, resulting in decreasing

seed quality of certain crops and resulting in the fall of commodity prices and consequently reducing farm income [6]. In such situation, the organic fertilizers play a major role in order to achieve sustainable agriculture. Organic fertilizer is a suitable source of macro and micronutrients [7]. To increase the quality of crops, especially medicinal and aromatic crops, organic fertilization are better than chemical fertilizers. Many investigators have pointed out the influence of organic manure by increasing the growth, yield and essential oil production of aromatic and medicinal plants [8]. Among organic fertilizers, farmyard manure (FYM) is a valuable source of nutrients and its yield increasing effect is well established [9].

Ahmed *et al*. [10] studied the effect of active dry yeast and farmyard chicken and animal manure on roselle plants and found that farmyard chicken significantly improved growth yield of calyces and active substance. Nabila and Aly [11] found that dressing both chicken manure and animal manure enhanced plant height, the number of branches and fruits, mass production of the plants, fresh and dry weights of sepals per plant. They also added that the total and soluble carbohydrates in the sepals, as well as ascorbic acid, positively responded all treatments. The organic farmyard manure enhanced roselle plant growth, fruit, and sepal yield [12]. The vegetative growth parameters, as well as the sepal yield of roselle plant, were increased when seeds were inoculated with *Rhizobium* and *Azotobacter* [13] or nitro-bin which a bio-source of nitrogen [14]. Inoculation of seeds with *Azotobacter* and *Azospirillum* in the presence of cattle manure resulted in improving both growth and yield. Gendy [15], reported that application of cattle manure fertilizer tended to a significant increase in fruit number/plant compared to control plants. The response of the dry weight of sepals/plant and dry weight of sepals' yield, to cattle manure fertilization, behaved similarly as that of the fruits number. Sufficient cattle manure application can be supplied N requirement of roselle and it can improve soil physical and chemical features, especially, nutrient retention, in the poor and infertile soils. In part, this may be associated with the release of nitrogen in the applied organic material which can improve roselle soil nutrient availability and soil biological activity.

It is suggested that there should be a complete or partial substitution of chemical source of nutrients minimizes the cost of chemical fertilizers and improves the efficiency and maintains soil health besides supplying nutrient to crops for higher productivity. Hence, this research was carried out to address the gap regarding the effects of farmyard manure on the growth, yield and yield components of roselle for the study area. Therefore, objective of this experiment is to determine the rates of farmyard manure on growth and yield of roselle.

II. MATERIALS AND METHODS

2.1. *Description of the Study Site*

The experiment was conducted at Hawassa research station during 16/2017 cropping season. The station is located at $7^{o}05'$ North latitude and $39^{o}29'$ 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.

2.2. *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 ^{O}C and 12-14 ^{O}C, respectively. Locally available and partially decomposed farmyard manure (FYM) was used as a source of organic input. The experiment was laid out in a randomized complete block design (RCBD) replicated four times. The treatments consisted of four levels of farmyard manure (0, 5, 10 and 15t ha^{-1}). Four blocks were prepared, in which all the treatments 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. 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 [16]. Plant populations were maintained by sowing three seeds per hill and thinning was done 15 days after sowing to obtain one plant per spot. Weeding and other cultural practices were done as required uniformly for all treatments.

2.3. *Soil Sampling and Analysis*

A composite 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 [17] in its bulletin with guide to laboratory establishment for plant nutrient analysis.

2.4. *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. 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. 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 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.

2.5. *Data Analysis*

For each measured response variable analysis of variance (ANOVA) and mean separation procedure was undertaken. Mean separation was done using least significant difference (LSD) at 5% probability level. All the statistical analysis was carried out using Statistical Analysis System (SAS) software version 9.3 [18].

III. RESULTS AND DISCUSSION

3.1. *Phenological and Growth Parameters*

The analysis of variance showed that farmyard manure (FYM) was highly significant ($P < 0.01$) for both days to 50% flowering and days to maturity of roselle. Application of 15 t ha^{-1} of farmyard manure increased days to 50% flowering and days to maturity by 14 % and 9 %, respectively compared to the control plot or to unfertilized plot (Table 1). Thus, plots treated with no organic fertilizer took shorter days to flower and mature than did fertilized plots. As the levels of 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. Oyewole and Mera [19], also reported that manure application promoted vegetative growth in roselle, while nitrogen had elongated the juvenile stage in plant, thus delaying crop maturity.

3.1.1. *Plant Height*

Application of farmyard manure was significantly affected plant height of roselle. Application of 15 t ha^{-1} of FYM resulted in tallest roselle plants (135.93 cm) and the shortest roselle plants were observed for the control (120.40 cm) treatment (Table 1). The increase in plant height due to application of higher rates of 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 [20]. Moreover, farmyard manures are also significant sources of major and micronutrients which are much needed by the plants for normal growth and development [21].

3.1.2. *Stem Diameter*

Application of farmyard manure significantly influenced stem diameter of roselle. The maximum (1.47cm) stem diameter was obtained at the application rate of 15 ton per hectare while the lowest (1.24cm) was obtained at control which is no application of farm yard manure (Table 1). The increase in stem diameter due to the application of farmyard manure might be because of the beneficial effects of FYM which could increase the growth of stem diameter and thus interpret as a cumulative increase in growth. Reports from Aluko *et al*. [22] indicated that thickest mid-stem diameters were obtained in jute mallow plants treated with 2.5 t ha^{-1} FYM and thinnest stem mid diameter was observed in unfertilized (control) plants. Similarly leaf area index was influenced by farmyard manure application rates. The highest leaf area index was recorded at application of 15 t per hectare and the lowest was observed at the control treatment (Table1).

Table 1. Effects of farmyard manure on date to 50% flowering (DTF), date to maturity (DTM), plant height (PH), stem diameter (SD) and leaf area index (LAI) at Hawassa.

FYM (t ha^{-1})	DTF	DTM	PH (cm)	SD	LAI
0	91.33^{c}	123.00^{c}	120.40^{c}	1.24^{b}	2.82^{b}
5	97.00^{b}	129.33^{b}	127.93^{b}	1.25^{b}	3.02^{ab}
10	102..00^{b}	132.67^{ab}	132.00^{a}	1.34^{ab}	3.05^{ab}
15	104.00^{a}	134.67^{a}	135.93^{a}	1.47^{a}	3.22^{a}
LSD (0.05)	3.13	4.32	4.04	0.14	0.25
CV (%)	1.99	2.08	1.96	6.49	5.23

FYM; farmyard manure, LSD = least significant difference; CV = coefficient of variation; numbers with the same letters are not significantly different ($P \leq 0.05$).

The increase in LAI might be due to nutrient release from FYM. Masrie *et al*. [16] reported that LAI increased by 162 and 134% due to application of 30 t ha^{-1} cattle manure over the control treatment in potato production.

3.2. *Yield and Yield Component Parameters*

3.2.1. *Number of Pods per Plant*

Application of farmyard manure influenced number of pods per plants. The highest pod numbers (55.91) were scored at the application rates of 15 t ha^{-1} FYM, but statistically at par with plot received 10 t ha^{-1} of FYM and the lowest (49.22) pod number was scored at the control or without farmyard manure (Table 2). In this particular study, as levels of NP fertilizers and farmyard manure increased; a number of pods per plant also increased. Similar work was reported by Akanbi *et al*. [23], a combination of 5. 0 t ha^{-1} of cassava peel compost (CPC) and 150 kg ha^{-1} NPK are adequate for optimum growth and pod yield of roselle. Gendy [15], reported that application of cattle manure fertilizer tended to a significant increase in fruit number/plant compared to control plants.

3.2.2. *Fresh and Dry Calyx Yield per Hectare*

This particular study result indicated that application of farmyard manure had significantly increased fresh and dry calyx yield of roselle over the control. The highest mean fresh and dry calyx yield per hectare (5.36t and 0.68t) was obtained in roselle plants received 15 t ha-1 of farmyard manure while the lowest (4.31t and 0.53t) per hectare was obtained in the plots without farmyard manure (Table 2). The increase in fresh and dry calyx yield might be due to the supply of an adequate amount of nutrients in the right proportion could influence the yield in roselle. This invariably affected the accumulation and partitioning of nutrients into the economic part of the plant [23] Haruna *et al*. [24], reported 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 was increased from 2.64 t ha^{-1} to 9.96 t ha^{-1} as compared to unfertilized roselle plant. Other scholars [19], reported that, for the production of the fresh calyx, the application of manure at 7.5 tons ha^{-1} showed the best yield. The report from Arsham [8], indicated that application of chicken manure (20 t ha^{-1}) + ostrich manure (20 t ha^{-1}) gave 1606 kg ha^{-1} dry calyx yield. The positive response of fresh and dry calyx yield of roselle to

manure conformed to the findings of Tindall [25], who reported that economic yield of roselle is only obtained on soils which are well supplied with organic materials and essential nutrients.

3.2.3. *Seed Yield per Hectare*

Seed yield per hectare was significantly influenced by farmyard manure rates. Application of 15t ha^{-1} of farmyard manure gave the highest (1.28t) seed yield per hectare. Statistically application of 5t and 10t per hectare of farmyard manure was not significant from the maximum treatment. Conversely, plot treated with no farmyard manure did show the lowest (0.99t) seed yield per hectare. Application of 15 t ha^{-1} of FYM seemed to contain sufficient amount of nutrients (Table 2). This could be the reason why roselle plant nourished with these treatments performed better than the control treatment. Sahoo and Panda [26], reported that higher seed yield (3269 kg ha-1) was obtained with the application of inorganic fertilizer along with farmyard manure at 5 t ha^{-1} compared to control (1323 kg ha^{-1}) or without application of organic fertilizers.

3.2.4. *Above Ground Dry Biomass*

Above ground dry biomass was also significantly influenced by the rates of farmyard manure. The highest (9.73t ha^{-1}) above ground dry biomass was obtained from application of 15t per hectare while the lowest was obtained from zero application of farmyard manure (Table 2). This result implied that as farmyard manure added to the roselle plant, the overall plant stands or size increased which contribute to the increment to the above ground dry biomass. Anyinkeng and Mih [27], reported that 20 tons of poultry manure significantly increase growth, biomass and economic yield of roselle. The biological and economic yield obtained from permanent plots, which were applied by 4-16 t ha^{-1} FYM [28], in case of maize. The increase in biological yield might be because of high nutrient availability in FYM that contributes to its dry biomass.

Table 2. Effects of farmyard manure on number of pods per plant (NPPP), fresh calyx yield per hectare (FCYPH), dry calyx yield per hectare (DCYPH), seed yield per hectare (SYPH) and above ground dry biomass (AGBM) at Hawassa.

FYM (t ha^{-1})	NPPP	FCYPH (t)	DCYPH (t)	SYPH (t)	AGBM (t)
0	49.22^{c}	4.31^{b}	0.53^{c}	0.99^{b}	6.50^{c}
5	51.95^{bc}	4.62^{b}	0.58^{bc}	1.15^{ab}	7.75^{b}
10	53.89^{ab}	5.07^{a}	0.63^{ab}	1.19^{a}	8.16^{b}
15	55.91^{a}	5.36^{a}	0.68^{a}	1.28^{a}	9.73^{a}
LSD (0.05)	3.42	0.33	0.07	0.16	0.64
CV (%)	4.06	4.20	7.73	8.68	5.00

FYM; farmyard manure, LSD = least significant difference; CV = coefficient of variation; numbers with the same letters are not significantly different ($P \leq 0.05$).

IV. CONCLUSIONS

Decline in soil fertility is one of the major challenges to crop production in Ethiopia. Therefore, different soil management practices such as the application of farmyard manure is needed to address the problem. Considering this, the experiment was conducted at Hawassa research station during 2016/2017 cropping season. The aim of this study was to evaluate effects of farmyard manure on growth, yield and yield components of roselle.

The results obtained from this study indicated that application farmyard manure significantly affected most traits of roselle. The highest and the lowest mean values of days to 50% flowering (104 and 91.33), days to maturity (134.67 and 123), plant height (135.93cm and 120.40cm), stem diameter (1.47 cm and 1.24 cm), leaf area index (3.22 and 2.82), number of pods per plant (55.91 and 49.22), fresh calyx yield per hectare (5.36t and 4.31t), dry calyx yield per hectare (0.68and 0.53t), seed yield per hectare (1.28t and 0.99 t) and above ground biomass (9.73t and 6.50t) were recorded at 15 t FYM ha^{-1} and 0 t FYM ha^{-1} application respectively. The results of the present study indicated that application of 15t FYM ha^{-1} improved calyx yield and yield components of roselle through improving soil physical characteristics and soil nutrient availability resulting in better vegetative growth, yield and yield components and thereby higher yield of calyx which is the main economic part of the plant. Therefore, roselle grower farmers and investors could be significantly enhanced if they applied 15t ha^{-1} of farmyard manure to roselle crop cultivated for roselle calyx production. However, this result needs to be confirmed by results of other experiments that should be conducted under the same and/ similar agro-climatic conditions and growing seasons.

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