International Research Journal of Plant Science (ISSN: 2141-5447)
Vol. 13(4) pp. 01-10, June, 2022
DOI: http:/dx.doi.org/10.14303/irjps.2022.021
Available online @ https://www.interesjournals.org/plant-science.html

Research Article

Evaluation of yield and economic profitability of using NP and FYM for the production of Roselle

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Abstract

Organic and inorganic fertilizers are one of the boosters of crop yield by full filling the crop nutrient demand. Other than their yield increment economic advantage of using this fertilizer should be known. The field experiment was conducted at Hawassa in 2017 to know yield and economic advantage of NP and FYM. The treatments consisted of four rates of inorganic (0/0, 23/10, 46/20 and 69/30 kg NP ha^{-1}) and four rates of FYM (0, 5, 10 and 15 t ha^{-1}) levels. The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times. Data was collected on yield and yield components alongside of economic analysis. The results revealed that the main effects and the interaction of NP fertilizers and FYM significantly ($p<0.05$) plant height, number of branches per plant, leaf area index, number of pods per plant, dry calyx yield per hectare, thousand seed weight and biological yield per hectare except calyx harvest index and thousand seed weight. The highest dry calyx yield (1.38 t ha^{-1}) was recorded at 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1}. The lowest dry calyx yield (0.529 t ha^{-1}) was obtained at the control treatment. The highest marginal rate of return (2435.75%) for dry calyx yield of roselle was recorded from the application of 46/20 kg NP ha^{-1} + 5 t FYM ha^{-1}. In conclusion, the results of this study indicated that applying 46/20 kg NP ha^{-1} in combination with 5 t FYM ha^{-1} led to the maximum benefit and recommended for the producers than other treatments.

Keywords: Calyx Yield, Economic Advantage, Inorganic Fertilizer, Organic Fertilizer, Roselle

INTRODUCTION

Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns (Bekeko, 2014). 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 (Tung & Fernandez, 2007). 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 (Taheri et al., 2011). 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 (Arsham, 2013). Among organic fertilizers, farmyard manure (FYM) is a valuable source of nutrients and its yield increasing effect is well established (Silvia et al., 2006).

However, organic inputs which are often proposed as alternatives cannot meet crop nutrients demands for large-scale production because of their relatively lower nutrient release as compared to inorganic fertilizers and it needs high application rates, high labor requirements, and limited availability (Palm et al., 1997). The use of farmyard manure alone may not fully satisfy nutrient demand, especially in the year of application (Patel et al., 2000). Soil fertility replenishment through the application of mineral and organic fertilizer is the way to effectively

Received: 25-May-2022, Manuscript No. IRJPS-22-64952; **Editor assigned:** 27-May-2022, PreQC No. IRJPS-22-64952(PQ); **Reviewed:** 10-Jun-2022, QC No. IRJPS-22-64952; **Revised:** 27-Jun-2022, Manuscript No. IRJPS-22-64952(R); **Published:** 04-Jul-2022

Citation: Lemma DT (2022). Evaluation of yield and economic profitability of using NP and FYM for the production of Roselle. IRJPS. 13: 021.

address these problems (Palm et al., 1997). Balemi (2012) had also suggested integrated nutrient management as an option to alleviate the problem and satisfy the crop's nutrient demand. It is suggested that there should be a complete or partial substitution of chemical fertilization by using organic fertilizers which are economical for farmers. The wise use of integrated organic and inorganic source of nutrients minimizes the cost of chemical fertilizers and improves the efficiency of added fertilizers and maintains soil health besides supplying nutrient to crops for higher productivity.

While adding fertilizers rather than their production increment the net return form applying fertilizer should be known and it economic advantage should be studied. In the study area the farmers use both organic and inorganic fertilizers without studying their economic advantage change in their life is not much? So this activity was designed to study the economic advantage of using organic and inorganic fertilizer as their enhancement of Roselle production.

MATERIALS AND METHODS

Description of the Study Site

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

Experimental Materials

'WG-Hibiscus-Sudan' variety which was registered by Wondo Genet Agricultural Research Center (WGARC) was used for this particular study as a test crop. It is well adapted in areas with an altitude of 1600-1800 m a.s.l at day and night temperature of 26-29°C and 12-14°C respectively. Urea (46-0-0) and triple superphosphate (TSP) (0-46-0) were used as sources of nitrogen and phosphorus, respectively. Farmyard Manure (FYM) locally available and partially decomposed 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 arrangements of 4x4 with three replications. 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}).

Experimental Procedures and Crop Managements

The land was prepared at Hawassa experimental site by removing all unwanted materials a month before sowing and the field was plowed with oxen, two times and seedbed/plot was prepared by using labor force. Three blocks were prepared in which all the 16 treatments were randomly assigned to the experimental units. Pathways between blocks and plots were 1.5m and 1m, respectively. Each plot had a size of 3.6 m x 1.8 m (6.48 m2) accommodating six rows with inter and intra-row spacing of 60 and 30 cm, respectively (Gebremedin, 2015). 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 based on a dry weight basis (Masrie et al., 2015). 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 phosphorous containing fertilizer was applied at the time of sowing. Nitrogen-containing Urea fertilizer was applied in split form (1/3 during sowing and the remaining 2/3 was applied before flower initiation (Akanbi et al., 2009). Weeding and other cultural practices were done as a required uniform for all treatments.

Soil Sampling and Analysis

Before the application of the treatments, a composite soil sample was collected following the standard soil sampling procedures at 0-30 cm soil depth. Uniformly slices and volumes of soils were obtained in each sub-sample by vertical insertion of an auger. Then collected composite soil sample was air dried, 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, soil pH, organic carbon, total N, available phosphorus, and cation exchange capacity (CEC) using standard laboratory procedures. The sample was also taken from farmyard manure and subjected to chemical analysis before incorporated into the soil, using the same procedures.

Organic carbon content was determined by the volumetric method (Walkley & Black, 1934) as described in Food and Agriculture Organization of the United Nations (FAO, 2008) guide to laboratory establishment for plant nutrient analysis using the prepared soil sample. The sample was analyzed for pH by using digital pH meter. The total number of exchangeable cations a soil can hold (CEC) was measured after saturating the soil with 1M ammonium acetate (NH_4OAc) and displacing it with 1 M NaOAc as described by Chapman (1965). Following the methods of Jackson (1962), total nitrogen in both soil and farmyard manure were analyzed by Micro-Kjeldahl digestion method with sulphuric acid. Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen et al., 1954). Particle size distribution was done by hydrometer method (differential settling within a water column) according to FAO (2008) using particles less than 2 mm diameter. The procedure measures percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm) and clay (<0.002 mm) fractions in soils.

Data Collected

The data on plant growth and yield-related traits were recorded from ten sample plants randomly selected from central rows in each plot, leaving aside, plants from the border rows and those at both edges of each row. The parameters considered for data collection were plant height, branch number, leaf area index, number of pods per plant, dry calyx yield, seed yield, thousand seed weight, harvest index, and above ground biomass.

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 a mean separation procedure using Duncan's New Multiple Range Test (DNMRT at the 5% probability level. All the statistical analysis was carried out using Statistical Analysis System (SAS) version 9.3.

Economic Analysis

The partial budget analysis was employed for economic analysis of fertilizer application and it was carried out for dry calyx yield data. The potential response of crop towards the added fertilizers and price of fertilizers during planting ultimately determine the economic feasibility of fertilizer application (CIMMITY, 1988). To estimate economic parameters, roselle calyces were valued at an average market price of 70.00 ETB/kg. To estimate the total costs, mean current prices of Urea (18.00 ETB/kg) and NPS (11.90 ETB/kg) were collected at the time of planting. Though TSP was used as a source of P, the price of NPS was considered for the calculation by equating the amount of P. An average of twenty-three workers for farmyard manure application and thirteen workers for NP fertilizer application were considered per hectare. The wage rate per worker was 50 ETB per day. Cost of land preparation, field management, harvest, transportation, protection, storage, planting material, post-harvest, and others was not included in the calculation since it was done uniformly for all treatments. The economic analysis was based on the formula developed by CIMMITY (1988) and given as follows:

Gross Average Yield (GAY) (kg/ha or ton/ha): is an average yield of each treatment.

Adjusted Yield (AJY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

AJY = GAY - (GAY * 0.1)

Gross Field Benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield.

GFB = AJY * field/farm gate price of a crop

Total Cost (TC): mean current prices of Urea (18 ETB/kg), NPS (11.9 ETB/kg), and the wages for NP and farmyard manure application were considered per hectare.

Net Benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment. NB = GFB – TC

Marginal Cost (MC) = change in costs between treatments

Marginal Benefit (MB) = change in benefits between treatments

Marginal rate of return {MRR (%)} = (MB/ MC)*100

RESULTS

Results of Soil Physicochemical Properties before Sowing

The result of physicochemical analyses of the soil at the experimental site before application of treatments is presented in **Table 1**.

Plant Height

The analysis of variance showed that there was significant (P≤ 0.05) interaction effect of inorganic (NP) fertilizers and farmyard manure on the plant height of roselle. The combined application of organic (FYM) and inorganic (NP) fertilizers produced plants that are taller than what was observed in the control. Application of 69/30 kg ha^{-1} of NP +15 t ha^{-1} of FYM gave the tallest roselle plant (194.33 cm) and the shortest roselle plant was recorded at the control (120.40 cm) treatment **(Table 2)**. The increase in plant height due to combined application of NP and FYM treatments may be attributed to an adequate supply of nutrients that influenced cell division and cell enlargement resulting in better plant height.

Number of Branches per Plant

A number of branches per plant were significantly influenced by the interaction effect of NP and farmyard manure. The results (Table 2) showed that plot treated with 69/30 kg ha^{-1} of NP + 10 t ha^{-1} of FYM was given the highest mean number of branches per plant (13.83), which was superior to all other treatments. While the lowest (5.2) branches $plant^{-1}$ was obtained from the control treatment.

Table 1. Selected physicochemical properties of the experimental soil and farmyard manure before sowing.

Physical property				Chemical properties				
Particle size distribution (%)			Texture class	pH(H_2O)	TN (%)	AP(ppm)	OC (%)	CEC (cmolkg^{-1})
clay	silt	sand	Sandy loam					
56	30	14		7.84	0.172	5.51	202	30.48
Farmyard manure				8.79	0.712	346.25	8.79	45.66

pH= power of hydrogen; TN= total nitrogen; AP= available phosphorus; OC= organic carbon; CEC= cation exchange capacity; ppm= parts per million; cmmolkg^{-1}= cent mole per kilogram.

Table 2. The interaction effects of inorganic (NP) fertilizers and farmyard manure on plant height, number of branches per plant, stem diameter and leaf area index at Hawassa.

NP (kg ha^{-1})	FYM (t ha^{-1})	PH(cm)	NBPP	LAI	NPPP	DCYPH (t)
0	**0**	120.40^{f}	5.2^{i}	2.82^{e}	49.22^{g}	0.529^{i}
	5	127.93^{ef}	6.27^{hi}	3.02^{e}	51.95^{fg}	0.583^{hi}
	10	132.00^{e}	7.13^{fgh}	3.05^{e}	53.89^{fg}	0.627^{ghi}
	15	135.93^{de}	7.56^{efgh}	3.22^{de}	55.91^{ef}	0.684^{gh}
23/10	**0**	129.73^{ef}	6.53^{gh}	3.07^{de}	55.56^{ef}	0.709^{fgh}
	5	132.8^{e}	7.87^{defg}	3.19^{de}	60.57^{de}	0.754^{efg}
	10	136.03^{de}	8.40^{def}	3.40^{de}	59.83^{de}	0.777^{ef}
	15	144.07^{cd}	9.13^{d}	3.47^{de}	62.30^{d}	0.820^{ef}
46/20	**0**	150.6^{c}	8.93^{de}	3.20^{de}	65.00^{cd}	0.846^{e}
	5	164.67^{b}	12.13^{bc}	3.75^{cd}	77.93^{b}	1.188^{cd}
	10	171.67^{b}	12.80^{abc}	4.23^{bc}	79.78^{b}	1.231^{bc}
	15	185.60^{a}	13.36^{ab}	4.47^{ab}	86.97^{a}	1.278^{abc}
69/30	**0**	163.73^{b}	11.33^{c}	3.45^{de}	70.54^{c}	1.056^{d}
	5	186.73^{a}	13.27^{ab}	5.13^{a}	87.25^{a}	1.312^{abc}
	10	193.00^{a}	13.83^{a}	4.64^{ab}	90.01^{a}	1.361^{ab}
	15	194.33^{a}	13.26^{ab}	4.57^{ab}	90.11^{a}	1.380^{a}
$CR_{0.05}$		9.60	1.63	0.68	5.90	0.13
CV (%)		3.73	9.98	11.41	5.16	9.01

CR= critical range; CV = coefficient of variation; PH= plant height; NBPP= number of branch per plant; SD= stem diameter; LAI= leaf area index; numbers with the same letters are not significantly different at ($P < 0.05$).

Leaf Area Index

Also, leaf area index was significantly influenced by the interaction effects of inorganic (NP) fertilizer and farmyard manure. As shown in Table 2, the maximum leaf area index (5.13) was obtained from plot received 69/30 kg ha^{-1} of NP fertilizers with a combination of 5 t ha^{-1} of FYM followed by application of 60/30 kg ha^{-1} NP + 10 t ha^{-1} of FYM (4.64). The lowest result (2.82) was observed in control treatment. The main effects of NP and FYM significantly influenced in which application of 69/30 kg ha^{-1} of NP fertilizer gave maximum leaf area index when applied alone and FYM with the maximum treatment 15 t ha^{-1} gave the high LAI than their respective treatments.

Number of Pods per Plant

The analysis of variance showed that a number of pods per plant were significantly affected by the combined effect of inorganic (NP) and FYM. The result of the present study revealed that the interaction between NP fertilizer and FYM was significantly affected a number of pods per plant of roselle. Among the interactions, application of 69/30 kg ha^{-1} of NP + 15 t ha^{-1} of FYM gave the maximum number of pods per plant (90.11), but statistically at par with plot received 46/20 kg ha^{-1} NP + 15 t ha^{-1} FYM, 69/30 kg ha^{-1} NP + 5 t ha^{-1} FYM and 69/30 kg ha^{-1} NP + 10 t ha^{-1} FYM. The lowest mean number of pods per plant (49.22) was obtained from control plot (Table 2).

Dry Calyx Yield per Hectare

Interaction effect between applied treatments (NP and manure) influenced dry calyx yield per hectare of roselle. The application of inorganic fertilizers (NP) in combination with farmyard manure affected dry calyx yield per hectare. The highest dry calyx yield 1.38 t per hectare was obtained when 69/30 kg ha^{-1} of NP integrated with 15 t ha^{-1} of FYM (Table 2). The lowest dry calyx yield 0.529 t per hectare was recorded at control treatment.

Thousand Seeds Weight

The analysis of variance depicted that thousand seeds weight of roselle was not significantly influenced by the applied FYM alone and their interaction. However, application of different NP fertilizer levels showed highly significant differences in thousand seed weight. The experimental result showed that application of inorganic fertilizer (NP) was increased thousand seed weight; maximum (32.52 g) and minimum (28.75 g) thousand seed weight were obtained at 69/30 kg ha-1 NP and control plot, respectively **(Figure 1)**.

Above Ground Biomass

Aboveground biomass responded significantly to the main effects of NP and FYM compared to the control treatment. The maximum aboveground biomass was obtained when 69/30 kg ha^{-1} of NP applied to the plant followed by application of 46/20 kg ha^{-1} of NP. As a result, aboveground biomass was increased from 8.04 t ha^{-1} to 12.26 t ha^{-1} while application of NP fertilizer increased from 0 to 69/30kg ha^{-1} **(Figure 2)**.

Partial Budget Analysis of NP and FYM Applications on Calyx Yield of Roselle

The result of this study revealed that the highest dry calyx yield (1380 kg ha^{-1}) was recorded at 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} which is followed by 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} (1361 kg ha^{-1}). Similarly, the highest adjusted dry calyx yield (1242 kg ha^{-1} and 1224.9 kg ha^{-1}) were obtained when 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} and 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} was applied respectively. The lowest was recorded at control treatment. The partial budget analysis indicated that the highest net benefit of (81180.15 ETB ha^{-1}) was recorded at 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} which was followed by 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} (80333.15 ETB ha^{-1}). The lowest net benefit (33327 ETB ha^{-1}) was obtained from the control which did not receive any fertilizers (Table 3). The high net benefit from treatments mentioned above could be mainly attributed to high dry calyx yield resulted from the interaction of NP and FYM while the low net benefit was attributed to low dry calyx yield due to the absence of adequate plant nutrients. From the above results, it is noticeable that the treatments with 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} and 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} have the highest net benefit than the rest of treatment combinations. Even though, these treatments showed a highest net benefit marginal rate of return should be incorporated to identify the best treatment that the farmers can be economically benefited from the application of fertilizers.

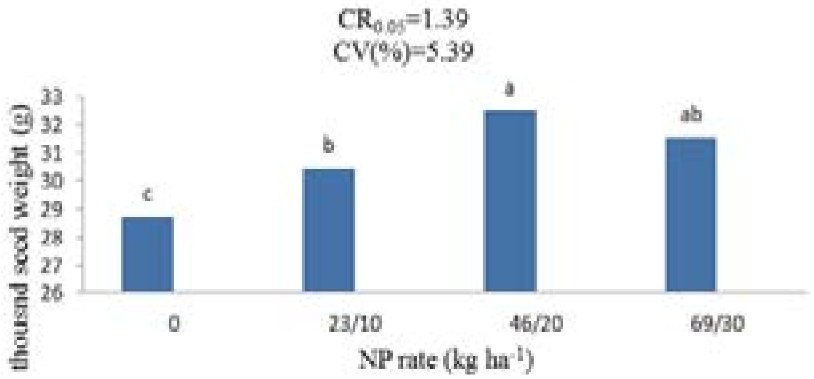

Figure 1. Effects of inorganic (NP) fertilizer on thousand seed weight at Hawassa during 2017 cropping season.

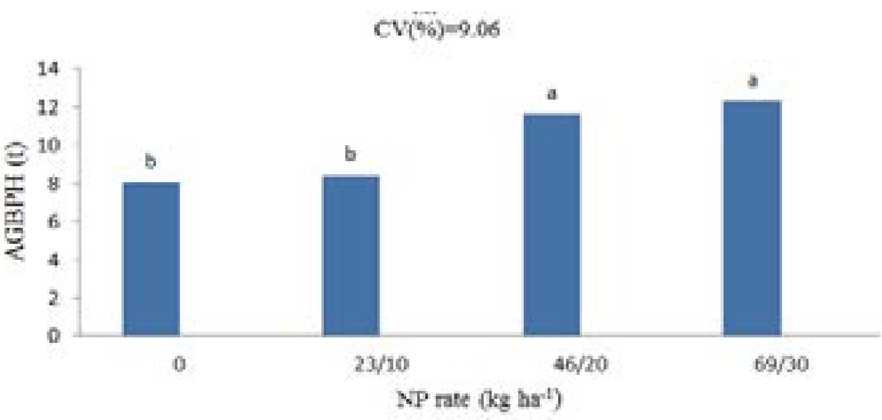

Figure 2. Effect of NP fertilizer on aboveground biomass of Roselle at Hawassa during 2017 cropping season.

Table 3. Partial budget analysis of NP and farmyard manure application on dry calyx yield of Roselle.

NP (kg/ha)	FYM (t/ha)	GAYC (kg/ha)	AJYC (kg/ha)	GFBC ETB/ha	TC ETB/ha	NBC ETB/ha	Dominance	MMR (%)
0	**0**	529	476.1	33327	0	33327		-
0	**5**	583	524.7	36729	800	35929		325.25
0	**10**	627	564.3	39501	1150	38351		629
0	**15**	684	615.6	43092	1500	41592		926
23/10	**0**	709	638.1	44667	1769.95	42897.05		483.44
23/10	**5**	754	678.6	47502	2519.95	44982.05		278
23/10	**10**	777	699.3	48951	2769.95	46181.05		479.6
46/20	**0**	846	761.4	53298	2989.9	50308.1		1921.82
23/10	**15**	820	738	51660	3219.95	48440.05	D	
46/20	**5**	1188	1069.2	74844	3789.9	71054.1		2435.75
46/20	**10**	1231	1107.9	77553	4139.9	73413.1		674
69/30	**0**	1056	950.4	66528	4259.85	62268.15	D	
46/20	**15**	1278	1150.2	80514	4489.9	76024.1		746
69/30	**10**	1361	1224.9	85743	5409.85	80333.15		782
69/30	**15**	1380	1242	86940	5759.85	81180.15		512

NP= Nitrogen and phosphorus; FYM= farmyard manure; GAYC=gross average calyx yield; AJYC= adjusted calyx yield; GFBC= gross field benefit of calyx; TC=total cost; NBC= net benefit from calyx yield; D= dominate

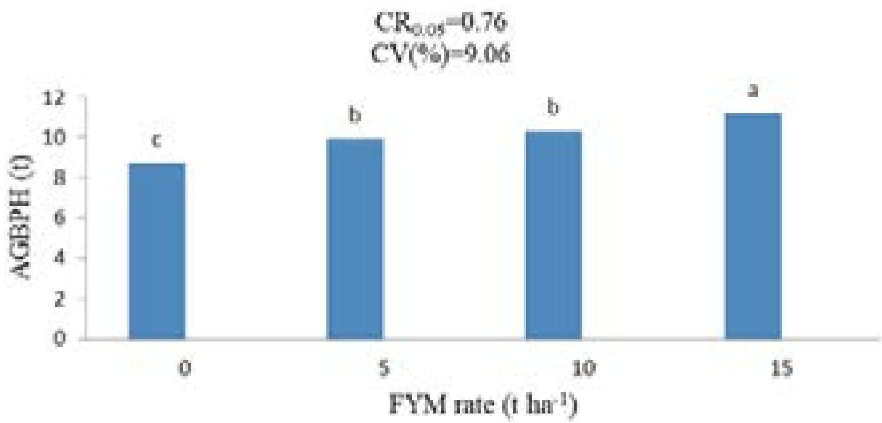

Figure 3. Effect of farmyard manure on aboveground biomass of Roselle at Hawassa during 2017 cropping season.

According to the result of the dominance analysis, treatments (23/10 kg NP ha^{-1} + 15 t FYM ha^{-1} and 69/30 kg NP ha^{-1} + 0 t FYM ha^{-1}) were dominated by other treatments **(Table 3)**. Because these treatments have net benefits less than treatments with lower variable costs. Such dominated treatments were dropped from the economic analysis for marginal rate of return. To identify treatments with the optimum return to farmers' investment, the marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a valuable option for farmers, 100% marginal rate of return (MRR) was considered as the minimum acceptable rate of return (CIMMITY, 1988).

According to the result of this study, marginal rate of return at 0 kg NP ha^{-1} + 5 t FYM ha^{-1} (325.25%), 0 kg NP ha^{-1} + 10 t FYM ha^{-1} (629%), 0 kg NP ha^{-1} + 15 t FYM ha^{-1} (926%), 23/10 kg NP ha^{-1} + 0 t FYM ha^{-1} (483.44%), 23/10 kg NP ha^{-1} + 5 t FYM ha^{-1} (278%), 23/10 kg NP ha^{-1} + 10 t FYM ha^{-1} (479.6%), 46/20 kg NP ha^{-1} + 0 t FYM ha^{-1} (1921.82%), 46/20 kg NP ha^{-1} + 5 t FYM ha^{-1} (2435.75%), 46/20 kg NP ha^{-1} + 10 t FYM ha^{-1} (674%), 46/20 kg NP ha^{-1} + 15 t FYM ha^{-1} (746%), 69/30 kg NP ha^{-1} + 5 t FYM ha^{-1} (275.82%), 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} (782%) and 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} (512%) were well above the 100% minimum (Table 3). From these treatments, the maximum marginal rate of return (2435.75%) was obtained at 46/20 kg NP ha^{-1} combined with 5 t FYM ha^{-1} which shows the highest profitability for the farmers. Based on this application of 46/20 kg NP ha^{-1} + 5 t FYM ha^{-1} remains profitable and recommended for farmers and growers at Hawassa and other areas with similar agro-ecological condition.

DISCUSSION

The textural class of the soil before the study conducted was sandy loam, with varying proportions of sand (56%), silt (30%) and clay (14%). According to the rating of Landon (1991), the soil used for this study was slightly alkaline (pH 7.84) and class indicating deficiency of certain plant nutrients. According to Olsen (1965), available soil P level of less than 5 ppm is rated as low; 5-15 ppm as medium and greater than 15 ppm is rated as high. Thus, the trial location had slightly medium (5.51 ppm) phosphorus. Following the rating of total N of > 1% as very high, 0.5 to 1% high, 0.2 to 0.5% medium, 0.1 to 0.2% low and < 0.1% as very low N status as indicated by Landon (1991), the experimental soil qualify for low (0.172%) total N. Similarly, the organic carbon (OC) content of the soil was also low (2.02%) in accordance with Landon (1991), who categorized OC content as very low (<2%), low (2-4%), medium (4-10%), high (10-20%) and >20% is very high. The CEC recorded in this study was high with a value of 30.48 cmol kg-1. According to Landon (1991), CEC by sodium acetate at pH 8.2 or ammonium acetate at pH 7.0 methods with values < 5, 5-15, 15-25, 25-40, and >40 are classified as very low, low, medium, high and very high. The low OC and low N content in the study area indicate low fertility status of the soil. This could be due to continuous cultivation and lack of incorporation of organic materials.

The beneficial effect of the application of farmyard manures along with inorganic fertilizers reflected in the enhanced growth of the plant. This may be attributed to the synergistic effect of farmyard manures in making available more plant nutrients by improving the soil physical and chemical conditions and solubilizing the nutrients. The increase of growth may also be due to readily available N from inorganic fertilizers which would be responsible for promoting better plant height (Tyagi et al., 2016). Nitrogen is a very important constituent of protoplasm and its favorable effect on chlorophyll content of leaves might have increased the synthesis of carbohydrates, amino acids, from which the phytohormones such as auxins, gibberellins, cytokinins, and ethylene have been synthesized resulting in increased plant height. Moreover, the farmyard manures are also significant sources of major and micronutrients which are much needed by the plants.

The positive response of NP fertilizers and farmyard manure to plant height of roselle indicates that nitrogen in farmyard manure and inorganic (NP) fertilizers facilitated the vegetative growth of the plant. Similar observations were made by Tisdale and Nelson (1966) that nitrogen was linked with vigorous vegetative growth in crop plants. A report from Arsham (2013) indicates that application of 20 t ha-1 of hen manure and 20 t ha-1 of ostrich manure gave the tallest roselle plant. The beneficial effect of NP and organic manure on plant height was investigated by other investigators (Swaefy et al., 2007) on the mint plant.

The findings of this experiment were also similar with the report of Gonzalez et al. (2001) who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients at growth stage resulting in an increase of growth variables including plant height. According to Akanbi et al. (2009), plant height in roselle increased from 145.9 cm in non-fertilized plants to 191.2 cm in a plant that received the highest rate of chemical fertilizer. Ojeniyi et al. (2007) also observed that NP and animal manure significantly increased plant height in tomato compared to the control treatment. Zhou et al. (2002) also reported that plants grown on soil treated with chemical fertilizers together with organic manure grow quite well by adjusting nutrients released into the soil.

This might be attributed to possible supplies of numerous plant nutrients to the plant from farmyard manure and NP fertilizes which might promote the lateral shoot growing. This result is in agreement with the report of Akanbi et al. (2009). They reported that all fertilized roselle plants progressively increased their number of main branches per plant from 3 branches of the control treatment to 8-10 branches per plant. According to Arsham (2013) application of (150, 100 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). Mohsen and Abdel-Fattah (2015) also reported that fertilization with N+P at 100+75 kg ha-1 gave the highest number of branch and the interaction between compost and N+P also reflected the significant effect on branch numbers of okra. The significant variation for a number of branches per plant was noticed due to these treatments in comparison other treatments, which clearly showed that application of a graded dose of N has proved to be beneficial in increasing the number of effective branches per plant as compared to control. The increase in a number of branches per plant due to nitrogen fertilization might be stimulated the plant metabolic activities, which resulted in more photosynthetic efficiency and also favored to initiation and extension of effective branches per plant.

The increase in LAI as interaction effect of NP an FYM might be due to nutrient release from FYM and NP fertilizers which contributed to plant growth parameters by increasing leaf area per plant and number of leaf because of the high amount of nutrient received. The result of this finding was similar to the report of Atta et al. (2010) and Atta et al. (2011) which indicated that leaf area index of roselle increased with the application of fertilizers. They reported that application of 50 and 100 kg ha-1 of nitrogen increased the maximum value of LAI from 5.5 $cm^2.cm^{-2}$ to 7.1 $cm^2.cm^{-2}$. Wondimu (2011) reported that the interaction due to P and N showed that a maximum number of leaf area index and it was attained at the combined level of 92 kg ha-1 and 120 kg ha^{-1}, respectively with an increment of about 34% over the leaf area index obtained at the control treatment in potato. Masrie et al. (2015) also reported that LAI increased by 162 and 134% due to the combined application of 120 kg N ha-1, 92 kg P2O5 ha-1 and 30 t ha^{-1} cattle manure over the control treatment. The reported from (Zerihun et al., 2013) showed that application of 110/46 kg ha^{-1} NP and 16 t ha^{-1} FYM gave highest LIA in maize and the lowest LAI was recorded at zero fertilizer application.

In this particular study, as levels of NP fertilizers and farmyard manure increased; a number of pods per plant also increased. This might be due to sufficient nutrients released from NP and FYM which enhances the vigorous growth of the plant and high amount of leaves which contributes to set high amount of pods per plant. Nutrient from NP and FYM improved vegetative growth, synthesis and translocation of photosynthesis from the sources to the sink, and a significant increase in a number of pods per plant. Similar work was reported by Akanbi et al. (2009), a combination of 5 t ha^{-1} of cassava peel compost (CPC) and 150 kg ha^{-1} NPK are adequate for optimum growth and pod yield of roselle. Also, the main effects of different rates of chemical (NP) fertilizers and farmyard manure showed a significant effect on yield and yield components of Roselle.

The increase in calyx yield of roselle as a result of NP and FYM application in combination may be attributed to an increase in photosynthetic area exhibited as a result of good vegetative growth which leads to high calyx yield. Also, high nutrient application promotes high dry matter accumulation due to nutrient translocation to the economic yield. 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 soil (Rao & Shaktawat, 2002). The finding of this experiment is in line with the report of Oyewole and Mera (2010). They observed that application of manure at 7.5 tons/ha or nitrogen at 75 kg N/ha gave the highest dry calyx yield. Increase in dry calyx yield might be due to the positive contribution of fertilizers to dry matter accumulation in plants. The report from Arsham (2013) indicated that application of chicken manure (20 t ha^{-1}) + ostrich manure (20 t ha^{-1}) gave 1606 kg ha^{-1} dry calyx yield. Also, the stimulating effect of NP and organic manures was investigated by Radwan and Farahat (2002) on kenaf plant. The positive response of dry calyx yield of roselle to manure conformed to the findings of Tindall (1983) who reported that economic yield of roselle is only obtained on soils which are well supplied with organic materials and essential nutrients.

Okosun (2010) reported that dry calyx yield responded positively to nitrogen and phosphorus in combination. They reported that application of 60 kg ha^{-1} of N and 30 kg ha^{-1} of P gave a good result. They observed that as the nutrient rates increasing the dry calyx yield was also increased from 586.3 kg ha^{-1} to 668.67 kg ha^{-1} for N and from 484 kg ha^{-1} to 720.33 kg ha^{-1} for P fertilizers applied than control treatment (unfertilized plots). Giginyu and Fagbayide (2009) also reported that dry matter responded best to 30 kg N + 50 kg P/ha and lowest mean was obtained from 0 kg N/ha which was 1.02 t ha^{-1} and 0.36 t ha^{-1} respectively. The report from Mera et al. (2009) indicated that the main effects of N and farmyard manure showed a significant effect from the control or from unfertilized plots on dry calyx yield. According to this author, 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. The authors recommended 2.5 t ha^{-1} farmyard manure and 50 kg N for production of the dry calyx.

The maximum seed weight for NP might be due to the positive effect of P on seed weight. The result is in line with the findings of Chimdessa (2016) that application of 110 kg ha^{-1} of N and 46 kg ha^{-1} of P gave maximum thousand seed weight than control treatment in maize. These results are in close conformity with (Sajid et al., 2012) who reported the application of 100 kg N ha^{-1} and 90 kg P ha^{-1} gave maximum 1000 seed weight of 65.0 g and minimum weight 51.67 g was recorded in control (without application of NP) in okra plant.

This result implied that as fertilizer added to the Roselle plant; the overall plant stand or size increased which contribute to the increment to the above-ground biomass. A similar result was reported by (Chimdessa, 2016) in which biomass yield was increased from 4.63 t ha-1 to 15.14 t ha-1 in maize when NP fertilizers applied than control. Similarly adding 15 t ha^{-1} of FYM was increased above ground by 28.08% over the unfertilized treatment **(Figure 3)**. The increments might be due to the positive effect of different nutrients found in farmyard manure to increase the dry biomass of the plant. Anyinkeng and Mih (2011) 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 (Zerihun et al., 2013).

CONCLUSION

The results obtained from this study indicated that application of inorganic fertilizers (NP) and farmyard manure influenced growth, yield and yield components of roselle. The interaction effects of NP and farmyard manure significantly affected plant height, number of branches per plant, leaf area index, number of pods per plant, and dry calyx 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), and dry calyx yield per hectare (1.38 t and 0.53 t) were obtained at 69/30 kg NP ha^{-1} +15 t FYM ha^{-1} and control respectively. Application 69/30 kg NP ha^{-1} + 10 t FYM ha^{-1} gave the highest number of branches (13.83) while the lowest (5.2) was obtained from the control.

The highest net benefit for dry calyx yield of roselle (81180.15 ETB ha^{-1}) was recorded from the application of 69/30 kg NP ha^{-1} + 15 t FYM ha^{-1} and the lowest (33327 ETB ha^{-1}) net benefit was recorded from the unfertilized plot. However, the highest marginal rate of return (MRR) (2435.75%) was obtained from the application of 46/20 kg NP ha^{-1} + 5 t FYM ha^{-1} which are economically more profitable for the farmers. The results of the present study indicated that application of 46/20 kg NP ha^{-1} + 5 t 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 components and thereby higher yield and benefit of the calyx. Therefore, cash incomes of roselle grower farmers and investors could be significantly enhanced if doses of NP (46/20) kg ha^{-1} in combination with 5 t FYM ha^{-1} are applied to Roselle crop cultivated for roselle calyx production.

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