Calyx Yield and Nitrogen Use Efficiency of Roselle (Hibiscus sabdariffa L.) as Affected by Variety and Levels of Nitrogen Fertilizer

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Abstract

Roselle (*Hibiscus sabdariffa* L.) is an important beverage and leafy vegetable plant. Its growth and yield attributes are affected by constraints like poor soil fertility and lack of improved varieties. A field trial was conducted to assess the Calyx yield response and nitrogen use efficiency of roselle. The experiment consisted of two roselle varieties (WG-Hibiscus-Jamaica and WG-Hibiscus-Sudan) and six levels of nitrogen fertilizer (Kg ha^{-1} (0, 23, 46, 69, 92, 105) laid out in factorial combination arrangement in randomized complete block design with three replications. Data on calyx yield, growth variables and nitrogen use efficiency parameters were recorded and analyzed by using SAS version 9.4. Results showed that the variety WG-Hibiscus-Jamaica exhibited higher plant height (196.2cm) and branch number $plant^{-1}$ (34.9) from the application of 115kg ha^{-1} N; while lower values of these attributes were recorded on an unfertilized plot of both varieties. Variety WG-Hibiscus-Sudan exhibited the highest number of calyx $plant^{-1}$ (50.3), fresh calyx yield ha^{-1} (5934 kg), and dry calyx yield ha^{-1} (1866 kg) from the application of 92 kg ha^{-1} N while lower values were recorded from the unfertilized plot of WG-Hibiscus-Jamaica variety. Higher NER (42.5 kg kg^{-1}) were recorded from WG-Hibiscus-Sudan while lower was recorded from WG-Hibiscus-Jamaica. Higher (12.5kg) and lower (0.7kg) AE were recorded from 92 and 115 kg ha^{-1} N application respectively. WG-Hibiscus-Sudan was effective but not reactive, while WG-Hibiscus-Jamaica was not effective but reactive. In conclusion, for maximum commercial produce, calyx yield and profitability, applying 69 kg ha^{-1} N on WG-Hibiscus-Sudan and 92 kg ha^{-1} on WG-Hibiscus-Jamaica was found best. Nevertheless, further investigation of the response and efficiency of roselle varieties to nitrogen fertilization, including other nutrients at different locations should be undertaken to get ample data for a conclusive recommendation.

Introduction

Roselle (*Hibiscus sabdarifa* L.) is an annual herbaceous shrub grown in the tropical and subtropical countries belonging to the family Malvaceae, (Morton, 1987). It has more than 300 species grown all over the world and wider genome diversity is found in Sub-Saharan Africa (Mohamed *et al.*, 2012). According to Murdock (1959), roselle is originated in West Africa and distributed to other parts of the world by African slaves. It is known by different names in different countries such as Jamaican Sorrel, karakade, roselle, bissap, zobbo, and Queens land jelly plant (El-Naimet al., 2012). It is a tetraploid (2n = 4x = 72) which has more related chromosome number with a diploid fibre crop (2n = 2x = 36) kenaf (Akpan, 2000). Roselle mainly adapts in areas with semi-humid to a subtropical climate in the altitudinal range of 600–2000 m above sea level and annual rainfall between 400–500 mm with an annual temperature ranging between 18–35ºC. It grows and performs well in well-drained, fertile soil with high organic matter and a pH of 4.5-8 (Babatunde et al., 2002; Olasantan, 2007).

Roselle is an economically important beverage, leafy vegetable, and medicinal plant used in several local dishes (Plottoet al., 2004; Atta et al., 2011). Its swollen fleshy calyx (sepals) is an economically important part which harvested by hand, dried, and sold completely into the herbal tea and beverage industry for food preparation in sauces, jams, juices, jellies, syrups, as a flavouring, and colouring agent for food and drinks; and also leaves as a leafy vegetable; seed as a valuable food resource on account of its protein, calorie and stem is as a substantial amount of fibre (McLean, 1973; Alegbejoet al., 2003). Its chemical composition of the calyx is approximately 15–30% made up of organic acids including citric, malic, tartaric, oxalic, stearic, and -Hibiscus acid which is most likely to contribute to the tartness of the herb and its teas and its health importance in the traditional medicine in the world are mainly attributed to the water extract of the roselle calyx (mainly as a mild laxative, antipyretic and diuretic) (Quisumbing, 1951; Mohamad, 2002). It is used in folk medicine for treating hypertension, pyrexia, liver damage, and cancer, as well as for its lipid-lowering and renal effects (Ibrahim and Hussein, 2006; Eltayeib and Elaziz, 2014).

Apart from nutritional and health importance, in developing countries, roselle plays an important role in income generation and subsistence among rural farmers and is relatively easy to grow and can grow as part of the multi-cropping system (Atta et al., 2011; Ibnouf et al., 2014). Its demand has steadily increased for roselle over the past decades. Approximately 15,000 metric tons enter into world international trades each year like Germany and the United States for consumption (Nath, 2007). However, in Ethiopia growth and yield of roselle are affected by various factors, such as the growing environment and sowing time (Khattak et al., 2016), application of organic and inorganic fertilizer (Alam et al., 2016; Sunday, 2016), and variety and irrigation managements (Khalil and Yousef, 2014), growing soil type and Soil nutrient status (Anyinkeng and Mih, 2011), insect pest, weeds and pathogens (Ansari *et al.*, 2013) and post-harvest handling (Plotto et al., 2004). It has an overall growing period of 4–6 months from seed sowing to harvesting of the calyx depending upon the growing environment and variety (Giginyu *et al.*, 2009).

Application of organic and inorganic fertilizers on roselle was reported as important and its performance increases with an increasing level of nitrogen application (Oyewole and Mera, 2010; El Naimet al., 2017). More importantly, the application of nitrogen significantly increases the growth and yield attributes of roselle by increasing till optimum farmyard manure or nitrogen level (Giginyu and Fagbayide, 2009). Its dry calyx yield ranges 388.48- 611.91 kg ha-1 for 0-100kg Nha-1 in Benin (Haruna et al., 2011). Moreover, 1200 kg ha-1 dried calyx yield was reported in Guinea (Giginyuand Fagbayide, 2009; Haruna et al., 2011; Mohamed, 2013). However, in Ethiopia, its yield is very low compared to those reports from other countries. Its Fresh calyx yield ha^{-1} (kg) ranges between 1855.8 and 2597.98 and dry calyx yield ha^{-1}(kg) ranges from 184.2 to 257.8 for variety WG-Hibiscus-Jamaica, whereas Fresh calyx yield ha^{-1}(kg) ranges between 1464.4- 1594.7 and Dry calyx yield ha^{-1}(kg) between 148.6-161.7 for variety WG-Hibiscus-Sudan. These data suggest an economic yield of roselle is far below (about more than 50% lower) that obtained in other countries, despite the potential of the varieties. Thus, the need for improving the economic yield of roselle by appropriate nitrogen fertilization as one agronomic strategy from recent information in Ethiopia, there are no reports on optimum nitrogen level fertilization of roselle varieties. With these rationales, the main aim of this study was (1) to evaluate the Calyx yield response of roselle varieties to different levels of Nitrogen fertilizer application and (2) nitrogen use efficiency of roselle varieties at different levels of nitrogen application.

Results And Discussions

Yield Response of Roselle Varieties to Levels of Nitrogen

As collected yield variable analysis result shows that the yield attributes of roselle were significantly *($p<0.05$)* affected due to verities and different levels of nitrogen application (Table 2). Higher and lower yield attributes were recorded from the application of 92 kg ha^{-1} N and unfertilized plots, respectively.   Percent increase for a number of calyx $plants^{-1}$ (26.3%), fresh calyx yield ha^{-1} (18.5%), dry calyx yield ha^{-1} (18.3%) economical yield (10.8%) from the application of 92 kg ha^{-1} N on WG-Hibiscus-Jamaica variety, and percent increase for a number of calyx $plants^{-1}$ (22.3%), fresh calyx yield ha^{-1} (22.5%), dry calyx yield ha^{-1} (20.3%) economical yield (22.8%) from the application of 92 kg ha^{-1} (Table 2). This possibility might be that nitrogen stimulates the growth and accumulate more biomass and set a potential increase in yield. But the extent of a percent increase in biological yield was greater than the economic yield, which might be that increase in the amount of nitrogen, possibly more accumulation to biomass growth which promotes more growth in biological yield rather than economical yield. A similar finding was reported by Blumenthal *et al.* (2008) application of nitrogen increases biomass yields as well as protein yield and concentration in plant tissue.

Higher economical yields were recorded from a lower level of nitrogen application while lower values for these attributes were recorded from the higher level of nitrogen application as compared to the moderate level of nitrogen. This might be that a higher amount of nitrogen application promotes more vegetative growth because more accumulation to biomass growth results from an increase in biological yield rather than economical yield. This finding is in agreement with Ullah *et al.* (2018) who found that higher biological yield was recorded from the higher level of nitrogen application while higher economical yield was recorded from the application of a lower level of nitrogen. However, a higher and lower value for all yield attributes was recorded from a variety WG-Hibiscus-Sudan and WG-Hibiscus-Jamaica, respectively. This might be due to the genetics of the variety which might lead to responding differently to applying nitrogen levels. This finding was in agreement with Khan and Dar (2006) who found that different yield attributes were recorded between varieties study done on the response of cotton to different levels of nitrogen application.

As the level of nitrogen increased, there was a slightly increasing and then decreasing trend for harvest index (Table-2). The possible reason might be that increase in the level of nitrogen promote more vegetative growth and an increase in biomass yield rather than accumulation to the economical yield. This finding was in agreement with Corte *et al.* (2016) who found that the seed yield and harvest index increase with increasing level of nitrogen up to 100kg/ha and then decreasing trend for a higher level of nitrogen application the study was done on the effect of nitrogen on agronomic yield, spad units and nitrate content in Roselle under dry weather condition. This finding is also in agreement with Hossain *et al.* (2010) who found that increasing the level of nitrogen up to 100 kg ha^{-1} increases fresh and dry calyx yield at wider spacing.

The possible reason for low fresh calyx yields from the higher level of nitrogen, the application was might be promoting vegetative growth like the number of primary and secondary branches which make them only set calyx on the only the top of the respective branch. In general, higher, and lower responses for yield attributes were recorded from WG-Hibiscus-Sudan and WG-Hibiscus-Jamaica, respectively from a different level of nitrogen application. This might be that difference in their extent of response which might be controlled by their growing environment interaction as well as root morphology. A similar finding was reported in Nigeria (Al-Sayed *et al.*, 2020; Norhayati *et al.*, 2019).

Nitrogen Use Efficiency of Roselle Varieties at different Levels of Nitrogen

Study results show nitrogen use efficiency of roselle was significantly ($p<0.05$) affected by the level of nitrogen and varieties. Higher values for efficiency parameters except apparent recovery efficiency were recorded from WG-Hibiscus-Sudan while lower values were recorded from WG-Hibiscus-Jamaica variety (Figure-1). As the level of nitrogen increased, there was a significant decrease in nitrogen efficiency ratio and agronomic efficiency possibly that nutrients accumulated in the above-ground part of the plant or the nutrients recovered within the entire soil-crop root system might be determined by the genetic makeup of cultivar and lower absorption and utilization of absorbed nutrients due to growing environment; consequently, results in reduced nitrogen efficiency ratio and agronomic efficiency. Similar findings were reported by Ghosh *et al.* (2015) study done on soil and input management options for increasing nutrient use efficiency. Conversely, as the level of nitrogen increased, a significant increase was recorded in physiological efficiency and apparent recovery efficiency (Figure 2).

Higher values were recorded for physiological and apparent recovery efficiency from the application of 115 kg ha^{-1} N which was statistically at par with 92 and 69 kg ha^{-1} N while lower values were recorded from the application of 23 kg ha^{-1} N. Possible reason for those differences in the efficiency of nitrogen between varieties might be a genetic capability that makes the ability of variety within species to absorb nutrients at a higher rate which makes plants responsible for efficient nutrient use at a low nutrient concentration of the growth medium.

A higher nitrogen efficiency ratio was recorded from an unfertilized plot of WG-Hibiscus-Sudan while a lower value was recorded from the application of 115 kg ha^{-1} N on variety WG-Hibiscus-Jamaica (Figure 2). This might be the potential reactiveness of roselle varieties to different levels of nitrogen. Similarly, higher agronomic efficiency was recorded from the application of 23 kg ha^{-1} N on WG-Hibiscus-Jamaica while a lower value was recorded from the application of 115 kg ha $^{-1}$ N on WG-Hibiscus-Sudan. Similar findings were reported by Argaw *et al.* (2015) who found that the highest agronomic efficiency was observed in soil having fertile soil with moderate N content, while the lowest was observed in soil with high soil fertility and N content study done in common bean.

Comparatively higher values for physiological and apparent recovery efficiency were recorded from WG-Hibiscus-Sudan while lower values were recorded from WG-Hibiscus-Jamaica. WG-Hibiscus-Sudan variety is non-responsive efficient while WG-Hibiscus-variety was responding and inefficient because later type of variety was lower yield at a lower level of nitrogen application and a slight increase in efficiency ratio decline when the level of nitrogen increase. On the contrary, a higher efficiency value was recorded from the lower level of nitrogen application from WG-Hibiscu-Sudan Variety and declined as the level of nitrogen increased (Figure-2). This possibly refers to better efficiency of WG-Hibiscus-Sudan Variety as compared to WG-Hibiscus-Jamaica Variety.

In Conclusion: The highest and lowest yield attributes and harvest index were recorded on the WG-Hibiscus-Sudan variety from the application of 92 kg ha^{-1} N and WG-Hibiscus-Jamaica variety, respectively. Similarly, higher nitrogen use efficiency except agronomic efficiency was recorded from WG-Hibiscus-Sudan while lower except agronomic efficiency was recorded from WG-Hibiscus-Jamaica variety for which higher agronomic efficiency was recorded. Among evaluated varieties to a different level of nitrogen application WG-Hibiscus-Sudan variety were observed as efficient but non-responding and WG-Hibiscus-Jamaica was observed as an inefficient and responding variety because for the former variety higher nitrogen efficiency ratio was recorded from a lower level of nitrogen application as compared to later variety. Thus, further study should be carried out on the response and efficiency of roselle with different levels of nitrogen, phosphorus at a different location to effectively estimate the efficiency, response and yield of roselle varieties.

Materials And Methods

3.1. Description of Study Site

The field experiment was conducted at Hawassa Green Mark Herb PLc. Experimental site during 2018/2019 under supplementary irrigation. The site was used for the rosemary experiment for three months. Geographically, it is located at 7^0 05’ North latitude and 39^0 29’ East longitudes in the Sidama Regional state at an altitude of 1652 meters above sea level (m.a.s.l) and receives a mean annual rainfall of 964 mm with a minimum and maximum temperature of 13°C and 27 °C, respectively. The soil textural class of the experimental site was sandy loam (Andosol) with a pH of 7.84 (Slightly basic) (Table 1).

3.2. Treatments and Experimental Design

Two introduced roselle varieties namely, WG-Hibiscus-Jamaica and WG-Hibiscus-Sudan released in 2014 for calyx production in low and mid-altitude of Ethiopia were used for this study. The combinations of six levels of Nitrogen (0, 23, 46, 69, 92, and 115 kg N ha^{-1} in the form of Urea) and two roselle varieties, formed twelve treatment combinations arranged in Randomized Complete Block Design (RCBD) and replicated thrice. The recommended level of phosphorus fertilizer 20 kg ha^{-1} (TSP:46% $P_20_{5)}$ was used as a source of phosphorus and Urea containing 46% N was used as a source of nitrogen and applied at three growth stages namely, seedling (25 days after an emergency); vegetative (75 days after an emergency) and flower bud initiation (115 days after an emergency). Both fertilizers were applied in-band applications during the sowing time for phosphorus and at different growth stages for nitrogen. Spacing between plots and blocks was 1 m and 1.5 m respectively. Each plot has a size of (3.6 m width x 3.6m length) /area of 12.96 m^2 and accommodates six rows with an inter-and intra-row spacing of 60cm$^{2.}$

3.3. Experimental Procedures

The experimental site was ploughed, disked, harrowed, and levelled manually, and blocking was arranged perpendicularly to the soil fertility/slope gradient. After blocking plots were arranged with adjusted spacing. The plots and experiment area were cleaned and a composite soil sample from a depth of 30 cm was collected from the experiment site to characterize the physicochemical property of the study site. All the treatments were assigned to each experimental unit, randomly with replication. Four seeds sowing were sown per hole, with 60 cm between plants and rows on the shoulder of the ridge. Thinning was performed after one month and one plant per hole was maintained. Urea was applied inside the dressing at three growth stages (seedling, vegetative, and flower bud initiation stages. Irrigation, weeding, and hoeing, as well as other cultural practices, were made as required. After harvesting soil samples were taken using an auger from each of the treatment plots. Soil samples collected both before sowing and after harvest were dried in the air and pulverized to pass through a 2mm sieve and subjected to analysis of the major soil physicochemical properties. Soil samples taken before sowing was analyzed for pH, organic carbon (OC), total nitrogen, available phosphorus, and CEC (cation exchange capacity) while after harvest samples were analyzed only for soil pH and total nitrogen; soil texture was determined by the hydrometer method; PH by using a pH meter; CEC was determined by using the 1N ammonium acetate method as described by Vance *et al*. (1987); Available phosphorus was estimated by using the Olsen extraction method as described by Olsen (1954); Total nitrogen was analyzed by Kjeldahl digestion procedure as described by Bremner, (1965); Plant tissue sampling was done at physiological maturity from six randomly selected plants that were harvested from central rows and partitioned into shoots and calyx. Then, shoots and calyx samples were separately air-dried and ground to pass one mm sieve. Nitrogen in shoots and calyx sub-samples were determined by using the method and guide to laboratory establishment for plant nutrient analysis suggested by Motsara and Roy, (2008).

Data collection

Data on growth and yield variables were collected from six plants of a central row as described below.

Plant height (cm): was recorded as total plant height from base to top including all flowering nodes at the harvesting stage; **Number of branches/plants**: was determined by counting the number of primary productive branches when the plants were at the harvesting stage; **Number of calyx per plant**: The capsules of six randomly selected plants from the central rows of each plot were harvested carefully when they mature and average capsules were determined: **Calyx yield plant^{-1} (g) (fresh):** The fully developed calyx of six randomly selected plants was peeled off from the capsules by using hand tools when they reach horticultural maturity and was measured immediately after peeling. Then the average fresh calyx yield per plant was determined; **Calyx yield per hectare** (kg) (fresh): a ratio of total harvested fresh calyx yield per plot to an area of harvested plot multiplied by 10,000m^2; **Calyx yield plant^{-1} (g) (dry):** The peeled fully developed calyx was dried by sunlight to constant weight, and then the average dry calyx yield per plant was determined; **Calyx yield plant^{-1} (g) (dry): a** ratio of total harvested dry calyx yield per plot to an area of harvested plot multiplied by 10,000m^2; **Harvest index (%):** is a ratio of economic yield to biological yield (aboveground biomass yield), was determined by using the following formula:- Harvest index = $\frac{\text{Economical yield (Calyx yield)}}{\text{Biological yield}} \text{X}100$

3.5. Analysis of Nitrogen Use Efficiency

Nitrogen use efficiency was done after determining the plant tissue analysis for total N concentration and estimating the N uptake (Baligar and Fageria, 2015) . N-uptake by leaves, calyx, and the seed was estimated as follows; N uptake = Concentrations (%) x dry matter

Total N uptake = shoots N uptake + calyx N uptake + seed N uptake Nitrogen efficiency ratio was estimated as suggested by (Gabelman and Gerloff, 1983) . To differentiate genotypes into efficient and inefficient nutrient utilizers. Nitrogen Efficiency Ratio (NER) = yield (kg) /Nitrogen in plant tissue (kg); Agronomic Efficiency (AE) was determined to evaluate economic production obtained per unit of nitrogen applied and was calculated as described (Baligar and Fageria, 2015) . Physiological Efficiency (PE) was calculated to estimate biological yield obtained per unit of nitrogen uptake/ increase in seed yield seed kg/N

Physiological Efficiency (PE kg/kg) =

$$\frac{\text{Biological yield of Nitrogen fertilized plot (kg)} - \text{Biological yield of Nitrogen unfertilized plot (kg)}}{\text{Nitrogen uptake of fertilized plot (kg)} - \text{Nitrogen uptake unfertilized plot (kg)}}$$

Apparent Recovery Efficiency (ARE) was calculated to determine a per cent increase in the uptake of Nitrogen in the fertilized plots as compared to Nitrogen unfertilized plots as described by (Baligar and Fageria, 2015) . Apparent Recovery Efficiency (ARE %) =

$$\frac{\text{Nitrogen uptake in a fertilized plot (kg)} - \text{Nitrogen Uptake in the unfertilized plot (kg)}}{\text{Amont of Nitrigen applied}}$$

Utilization Efficiency (UE): was estimated as a product of physiological efficiency and apparent recovery efficiency and it was estimated as described by (Baligar and Fageria, 2015) .

UE kg/kg= $\text{Physiological Efficiency (PE) X Apparent Recovery Efficiency (ARE \%)}$

3.6. Data Analysis

Data analysis was done using the proc mixed model procedure of software (SAS) version 9.4 (SAS, 2014) . The least significant difference (LSD) test was used to compare treatment means at a 5% probability level.

Declarations

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Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Each author was contributed to Proposal writing, Data Collection, and research report Writeup.

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Tables

Table 1. Physicochemical Properties of the Soil Sample Before Planting

Physiochemical properties	Unit	Test methods used	Values	Remark
PH	Soil: water	PH meter	7.8	Slightly basic
Soil Organic matter	%	Volumetric method	3.52	
Organic carbon content	%		2.02	Low
Total nitrogen	%	Kjeldahl technique	0.070	Very low
Available phosphorus	Ppm	Olsen	76.27	High
EC (µs/cm)	ds/cm		111.6	Saline
CEC	(Meq/100g)	1N ammonium acetate	30.48	High
Sand	%		56	
Clay	%		14	
Silt	%		30	
Textural class			Sandy loam	

Table 2. Yield Response Roselle Varieties to the Different Levels of Nitrogen Application at Hawassa, South Ethiopia

Variety	Level of Nitrogen (kg ha^{-1})	Number of calyxes $plant^{-1}$	Fresh Calyx Yield (kg ha^{-1})	Dry Calyx Yield (kg ha^{-1})	Seed Yield $Plant^{-1}$ (g)	1000 Seed Weight (g)	Biological yield (kg ha^{-1})	Economical yield (kg ha^{-1})	Harvest index (%)
WG - Hibiscus-Jamaica	0	15.1^{d}	4329^{d}	1319^{c}	7.9^{dc}	20.7^{f}	15046^{c}	4552^{b}	30.3^{c}
	23	15.6^{d}	5067^{bC}	1583^{b}	8.3^{dc}	27.7^{de}	15664^{c}	5324^{b}	34.0^{c}
	46	16.9^{d}	4747^{bcd}	1580.5^{b}	9.7^{bcd}	26.7^{de}	18519^{b}	5015^{b}	27.1^{c}
	69	17.1^{d}	4645^{dc}	1618^{b}	11^{bcd}	25.6^{e}	18519^{b}	4938^{b}	26.7^{c}
	92	17.2^{d}	5403^{ab}	1616^{b}	7.9^{dc}	25.7e	22377^{a}	5556^{bc}	24.8^{c}
	115	19.3^{d}	5309^{ab}	1610^{b}	6.9^{d}	28^{de}	20833^{a}	5478^{b}	26.3^{c}
WG - Hibiscus-Sudan	0	34.6^{c}	4605^{dc}	1677.7^{ab}	10.8^{bcd}	32^{bc}	6250^{e}	4861^{b}	77.8^{a}
	23	39.2^{bc}	4944^{bcd}	1730.5^{ab}	12.4^{abc}	25.3^{e}	5324^{e}	5247^{b}	98.6^{a}
	46	41.9^{b}	4925^{bcd}	$1751a^{b}$	14.6^{ab}	25.6^{cde}	6250^{e}	5324^{b}	85.2^{a}
	69	43.8^{b}	5046^{bc}	1705.5^{ab}	16.5^{ab}	47.3^{a}	6327^{e}	5478^{b}	86.6^{a}
	92	50.3^{a}	5934^{a}	1866.6^{a}	12.9^{abc}	33.3^{b}	7639^{e}	6250^{a}	81.8^{a}
	115	40.6^{bc}	4982^{bcd}	1580.5^{b}	10.1^{bcd}	29.7^{cd}	11188^{d}	5247^{b}	46.9^{b}
Mean		29.3	4994.5	1636.5	10.7	29.2	12828	5273	53.8
LSD (0.05)		6.2	659.73	233	5.0	3.6	1900	613	23.3
CV (%)		12.6	7.8	8.4	27	7.3	21.2	7.4	8.4

Means with the same letter were not significantly different CV = percent coefficient of variation; LSD=Least significance difference

Figures

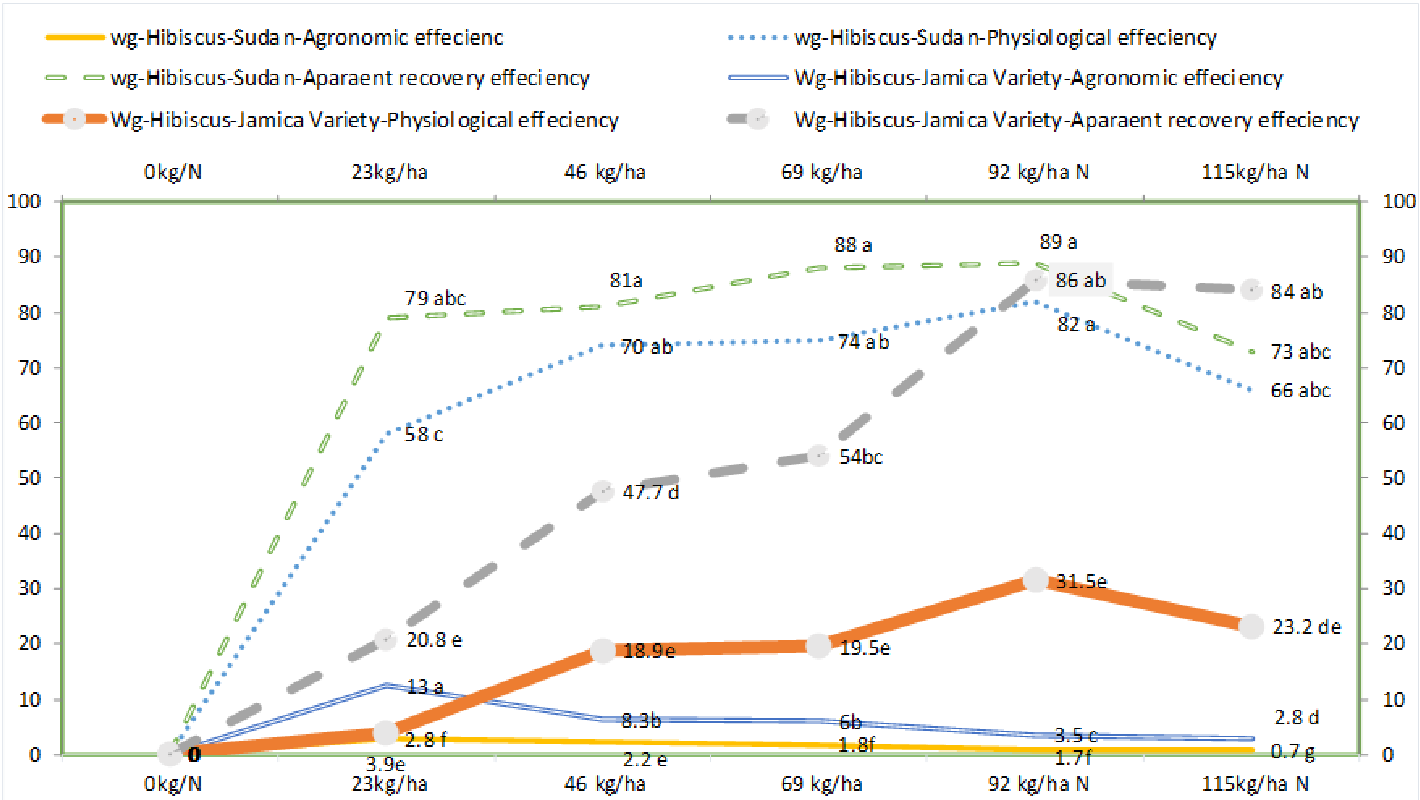

Figure 1

Nitrogen Uses the Efficiency of Roselle Verities at Different Level of Nitrogen Application at Hawassa South Ethiopia

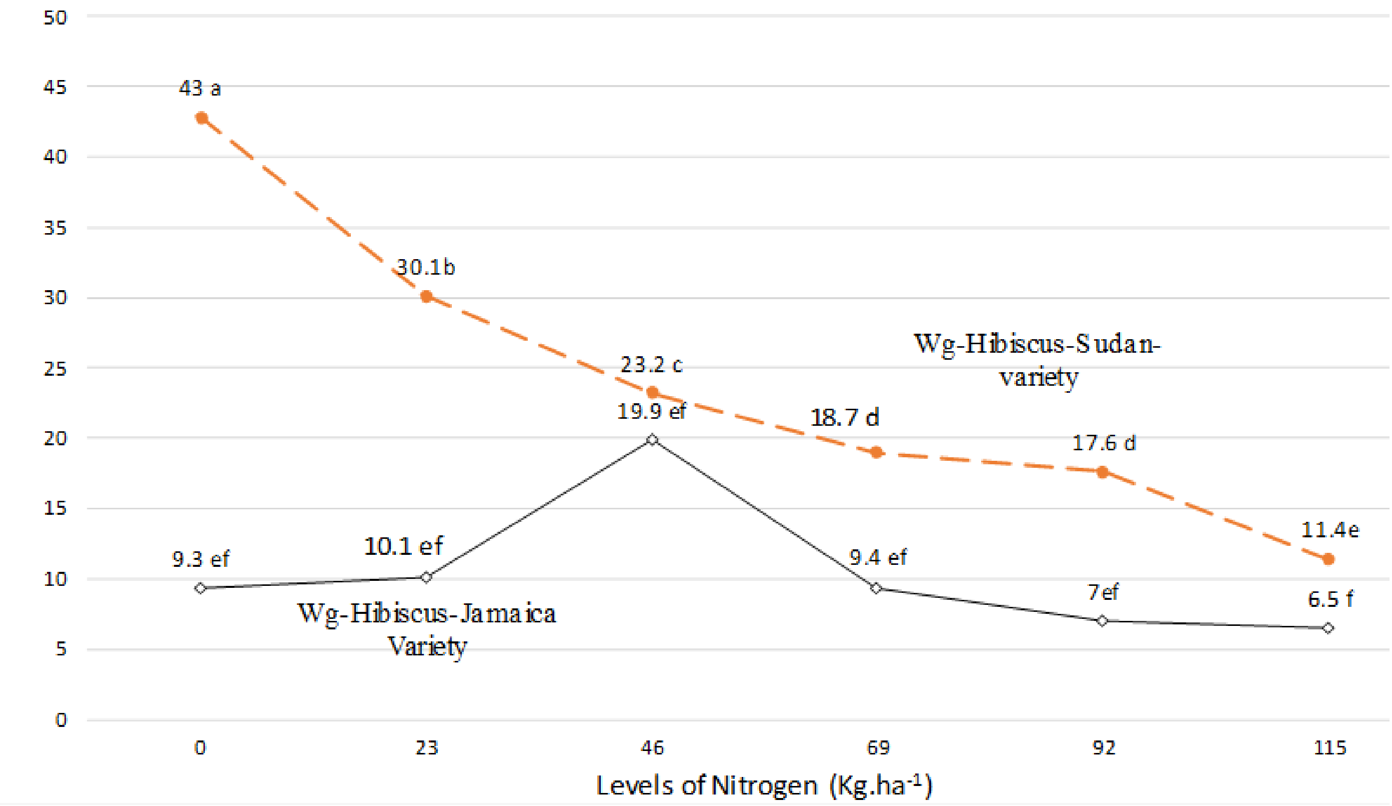

Figure 2

Nitrogen Efficiency Ratio of Roselle as Affected by Different Levels of Nitrogen