Effect of chemical and organic fertilizers on growth and yield of two roselle (*Hibiscus sabdariffa* L.) cultivars

E I M Ibrahim, A A AbdElbagi and E H A Ahamed

Department of Agronomy, Faculty of Agriculture, Omdurman Islamic University, Fitaihab, Omdurman, Sudan

E-mail: ahamedelkheir@yahoo.com

Abstract. Chemical and organic fertilizers are limit factors of crops growth. A field experiment was conducted for two consecutive summer seasons (2011 and 2012) at the Demonstration Farm of the Faculty of Agriculture, Omdurman Islamic University (Fitaihab). The objective of the study was to investigate on the effect of chemical and organic fertilizers on growth and yield of roselle (*Hibiscus sabdariffa* L.). Two varieties namely Bulk (V1 – local) and Omshiback (V2- improved) were used to assess their performance in respect to application of chemical and organic fertilizers. Chemical fertilizer involved 0, 40, 80 kg N/fed and 40 N + 40 kg P<sub>2</sub>O<sub>5</sub>/fed, whereas fermented organic fertilizers were 2 ton chicken manure/fed and 3 ton cattle manure/fed. The experiment was designed in a split-plot design with four replications. The findings of the study reveal that, among the two varieties, there were no significant differences between them for all studied parameters (plant height, number of nodes/plant, number of leaves/plant, leaf area, number branches/plant, plant dry weight and yield of dry calyces), except number of nodes/plant during the 1<sup>st</sup> season, when V1 significantly exceeded V2 for this parameter. Meanwhile, application of chemical and organic fertilizers significantly affected only number of leaves/plant only during the 1<sup>st</sup> season, when both F1 and F2 treatments obtained the significantly higher mean of this parameter as compared to the other treatments.

1. Introduction

Roselle (*Hibiscus sabdariffa* L) is a member of the family of Malvaceae. Roselle is an ornamental and medicinal plant or annual herb but provides limited annual plants in some environments, which are essential yearly plants that are successfully grown in tropical and sub-tropical regions [1,2]. Throughout Roselle growing regions, the crop is grown traditionally without application of chemical or organic fertilization, although it reacts favorably to these fertilizers when researched, by growing more vigorously.

Van Damme and Viaene [3] stated that for vigorous growth, regular supply of plant nutrients, especially the macro elements is necessary. Enwezor et al. [4] mentioned that the soils of savanna zone are predominantly coarse-textured and characteristically low in organic matter and hence are potentially low in natural fertility and therefore cannot sustain high crop yield under continuous cultivation without application of fertilizers. Duke and Aychely [5] mentioned that roselle plants responded favorably to nitrogen fertilizer. Adamson et al. [6], Rhoden and Small [7], Rhoden et al. [8] and Atta et al. [9] stated that for high yield of calyces, high rate of nitrogenous fertilizer is needed, but
the nutritional requirements of roselle is unknown. Nitrogen is an essential nutrient for maximum results in most plants/crops [10].

The growth rate of Roselle was increased as level of nitrogen increased [11]. Gibson and Waring [12] found that yield of Roselle was increased when the crop followed legume crops. Hago and Oman [13] observed that the growth and yield of roselle were significantly affected by application of both nitrogen and phosphorus, but phosphorus had less effect on growth of Roselle than nitrogen. Similar results were also reported by Abdelbagi [14]. Abu Elseoud et al. [15] stated that application of compost to newly reclaimed soils significantly increased both the dry matter and yield of fruits for the cultivated roselle. Gad [16] observed that the application of both chicken and cattle manure significantly improved roselle growth (plant height and number of branches/plant) as well as calyces fresh and dry weight as compared to control. This work was conducted in order to investigate on the effect of chemical and organic fertilizers on the growth and yield of Roselle.

2. Materials and Methods

2.1. Location and description of experimental layout

A field experiment was carried out during two consecutive summer seasons (2011 and 2012) in the Demonstration Farm of the Faculty of Agriculture, Omdurman Islamic University (Fitaihab), latitude 15° 34’ N, longitude 32° 34’ E and 393 m above sea level. The soil suffers from low depth and fertility with pH ranging between 7.0 – 7. Two varieties of Roselle (Hibiscus sabdariffa L.) were used namely Bulk (as local variety, characterized by red stem and small seeds), which referred to as V1 and Omshiback (as certified variety, characterized by dark red stem and large seeds) referred as V2. The seeds of both varieties were obtained from Elobaied Research Station, Agriculture Research Station – Sudan (production of 2009/2010 season). The fertilizer treatments of the present study consisted of two chemical fertilizers (N and P) and two organic fertilizers (cow and chicken manure), in addition, to check treatments (F0). Nitrogen treatments were 40 kg N/fed (referred to as F1), 80 kg N/fed (referred to as F2), and a combination of 40 kg N/fed + 40 kg P2O5/fed (referred to as F3). Cow and chicken were firstly fermented in form of compost and then added as 3 tons/fed cow manure (referred to as F4) and 2 tons/fed chicken manure (referred to as F5). The process of formulation of both cow and chicken manure as compost was done according to Billington [17]. Sowing date was in the 3rd week of July for both 2011 and 2012 seasons. The experiment was laid out in a split-plot design with four replications according to Gomez and Gomez [18]. The varieties were allotted in the main plots, whereas the fertilizers treatments were designated in the sub-plots.

2.2. Husbandry

Before sowing, the stable of the previous crops was removed from the experimental area. The land was then disc-plowed, leveled and then ridged at 70 cm spacing. The experimental unit was a plot of 12.5 m² (5 m × 2.5 m) in area and consist of 6 ridges, each 2.5 m in length. The crop was sown on 20th July for the two seasons. Five seeds per hole were sown on the top of the ridge at 50 cm spacing between holes. Phosphorus, cow and chicken fertilizers were then applied on the bands of one side of the ridge at the depth of near 3 inches, while nitrogen fertilizer was broadcasted. The crop was immediately irrigated after sowing and then irrigated consequently every 7 days; accordingly, the crop received 14 irrigations during the season, which extended to about 4 months. Thinning to 2–3 plants/hole and re-sowing were carried out after the 3rd irrigation for both seasons. Three manual weedicings were done after the 3rd, 5th, and 7th irrigation. No pesticides or fungicides were used in both seasons.

2.3. Growth and yield attributes

After the plant well established, five plants from the four central ridges in each plot (treatment) were randomly selected and tagged to study the following characters
2.3.1. **Plant height (cm)**. This parameter was measured for the five selected plants from the base immediately above the soil to the tip of the youngest leaf at 14th week from sowing using tap meter and then plant height for each treatment was determined.

2.3.2. **Numbers of nodes / stem**. Nodes at the main stem from which leaves raised were counted at the 14th week from sowing.

2.3.3. **Number of leaves/plant**. This parameter determined every 15 days starting at 14th week from the sowing up to maturity.

2.3.4. **Leaf area (cm²)**. Randomly 5 leaves from 5 selected plants were taken fresh at 14th week and then butchered using buncher, after that the disc and the rest leaves were air-dried and from their dry weight leaf area were calculated according to the formula:

\[
\text{Leaf area} = \frac{\text{dry wt of the whole leaf} \times \text{area of the buncher}}{\text{dry wt of the disc leaf}}
\]

2.3.5. **Number of branches/plant**. After 12th weeks, all set-up branches in the five selected plants were account and then mean of number of branches/plant for each treatment was determined.

2.3.6. **Plant dry weight (g)**. From the two outer ridges of each plot, five plants were gently uprooted, air-dried and then frequently weighed using a me-teller sensitive balance. This measurement was taken 14th week from sowing.

2.3.7. **Dry calyx yield (kg/fed)**. After 120 days from sowing, most fruits reached maturity in both seasons, when their capsules turned from green to yellowish color and started to crack at the tip. At this stage, fruits of plant in an area of 4.2 m² (6.0 m × 0.7 m²) in the 4 central ridges (1.5 m each) were picked from each plot. Then calyces were air dried and weighed to obtain calyces dry weight (kg/fed.) according to the equation:

\[
\text{Dry calix yield} = \frac{4200 \times \text{harvested area}}{4.2 \times 1000}
\]

2.4. **Statistical analysis**

Data were analyzed using Analysis of Variance (ANOVA) according to Gomez and Gomez [17]. Mean separation for the treatment means was done by using Duncan's Multiple Range Test (DMRT).

3. **Results and discussion**

3.1. **Plant height**.

Table 1 shows that plant height in both seasons (2011 and 2012) was not significantly affected by Roselle varieties, although it was higher in V₁ (Bulk) than in V₂ (Omshiback) by about 20.6% for the 1st season and 15.1% for the 2nd season. Similarly, this parameter was also not significantly affected by application of different types of fertilizer, but table 1 indicates that F₁ (40 kg N/fed.) in both seasons achieved in significantly higher mean of pant height (104.1 and 88.6 cm, respectively) than other fertilizer treatments.

3.2. **Number of nodes/plant**.

In both seasons, number of nodes/plants was slightly higher under V₁ (39.9 and 28.9, resp.) as compared to V₂ (34.2 and 27.7, respectively), but it was significantly different in the 1st season. The slightly higher number of nodes for V₁ than V₂ resulted in plant height for this variety as shown previously. Application of chemical and organic fertilizers did not significantly affect number of
nodes/plant of Roselle and F₁ treatment as shown in table 1 slightly increased this parameter than other treatments, but with no significant differences. Many studies indicate that the number of nodes is genetic control rather than environmental influences.

3.3. Number of leaves/plant
This parameter was statistically insignificant between varieties in both seasons, but it was significantly affected by fertilizer during the 1st season (Table 1). During the 1st season, F₁ reported a significantly higher mean of number of leaves/plant (169.7) in comparison of all other studied fertilizer treatments, except F₂ (140.3). This result may indicate the response of roselle plants to the low as well as high doses of N fertilizer in relation to the number of leaves/plant. This result was in line of Duke and Aychely [5], Van Damme and Viaene [3], Hago and Oman [13] and Abdelbagi [14].

| Treatments | Plant height (cm) | No. of nodes/plant | No. of leaves/plant | Leaf area (cm²) |
|------------|------------------|---------------------|---------------------|----------------|
| Varieties  |                  |                      |                     |                |
| V₁         | 105.0ᵃ           | 82.3ᵃ               | 39.9ᵃ               | 139.0ᵃ         |
| V₂         | 87.1ᵃ            | 71.5ᵃ               | 34.2ᵇ               | 110.9ᵃ         |
| S.E        | 8.3              | 1.6                 | 0.43                | 6.9            |
| Fertilizers|                  |                      |                     |                |
| F₀         | 97.9ᵃ            | 80.9ᵃ               | 37.3ᵃ               | 101.4ᶜ         |
| F₁         | 104.1ᵃ           | 88.6ᵃ               | 40.9ᵃ               | 169.7ᵃ         |
| F₂         | 89.8ᵃ            | 71.1ᵃ               | 35.9ᵃ               | 140.3ᵇ         |
| F₃         | 92.8ᵃ            | 69.9ᵃ               | 36.9ᵃ               | 118.3ᵇ         |
| F₄         | 95.5ᵃ            | 80.1ᵃ               | 33.7ᵃ               | 104.5ᵇ         |
| F₅         | 96.1ᵃ            | 78.4ᵃ               | 37.6ᵃ               | 115.4ᵇ         |
| S.E        | 6.7              | 6.7                 | 2.5                 | 13.1           |

Means within columns which having similar letters are not significantly different at 0.05 level of probability according to DMRT.

3.4. Leaf area (cm²)
Table 1 demonstrates that neither genotypes nor fertilizer application statistically affected leaf area of roselle and it was ranged between 10.5 cm² for V₁ during the 1st season and 8.8 cm² for the same variety during the 2nd season, and between 11.3 cm² for F₃ during the 1st season and 7.7 cm² for F₀ during the 2nd season.

3.5. Number of branches/plant
Number of branches/plants did not significantly affect by genotype and fertilizers in both seasons as shown in Table 2. Although there were no significant differences between varieties for this character, but Table 2 shows a slight increase in this character under V₁ as compared to V₂, particularly in the first season, when V₁ increased this parameter as compared to V₂ by about 18.0%. Similarly, F₁ in the 1st season and F₀ in the 2nd season obtained in significantly higher mean of this character as compared to the other treatments. The insignificant effect of application of fertilizer in this study towards plant height in both seasons and number of leaves in the 2nd season may be behind the insignificant effect of these treatments on branches/plants.
3.6. Plant dry weight (g)

Table 2 shows that plant dry weight of Roselle was not significantly affected by both genotypes and applied fertilizer in both seasons. It was observed that in both seasons, F_1 treatment reported in significantly higher mean of this parameter (40.1 and 35.5 g, respectively), which may be attributed to the better performance of this treatment regarding the vegetative growth as shown previously.

| Treatments | No. of branches/plant | Plant dry wt (g) | Dry calyces yield (kg/fed.) |
|------------|-----------------------|------------------|----------------------------|
|            | 2011 | 2012 | 2011 | 2012 | 2011 | 2012 |
| Varieties  |      |      |      |      |      |      |
| V_1        | 28.9^a | 23.5^a | 36.4^a | 28.4^a | 200.54^a | 150.50^a |
| V_2        | 24.5^a | 22.9^a | 37.4^a | 29.6^a | 168.58^a | 124.00^a |
| S.E±       | 1.2  | 0.37 | 2.6  | 2.9  | 12.81 | 17.77 |
| Fertilizers|      |      |      |      |      |      |
| F_0        | 31.1^a | 29.5^a | 32.5^a | 24.7^a | 160.75^a | 114.75^a |
| F_1        | 39.8^a | 25.0^a | 40.1^a | 35.50^a | 208.38^a | 150.88^a |
| F_2        | 26.2^a | 24.2^a | 28.3^a | 31.6^a | 200.38^a | 110.63^a |
| F_3        | 26.1^a | 19.6^a | 36.3^a | 26.8^a | 175.75^a | 156.75^a |
| F_4        | 22.6^a | 24.7^a | 39.7^a | 30.5^a | 185.88^a | 153.63^a |
| F_5        | 27.6^a | 23.0^a | 43.7^a | 24.5^a | 176.25^a | 136.88^a |
| S.E±       | 1.97 | 1.2  | 5.8  | 5.8  | 21.28 | 46.91 |

Means within columns that having similar letters are not significantly different at 0.05 level of probability according to DMRT.

3.7. Dry calyx yield (kg/fed.)

Yield of dry calyx as shown in table 2 was not significantly affected by both genotype and application of chemical and organic fertilizers, but it was observed that it was insignificantly increased in V_1 than in V_2 by about 19.0% for the 1st season and 21.4% for the 2nd season, which may indicate better performance of this variety regarding growth and yield components. On the other hand, both F_1 in both seasons achieved insignificantly higher dry calyces yield as compared to the other fertilizer treatments. The slight increment in dry calyces yield under this treatment may be attributed to its effect on growth parameters as well as yield components. Similar results were also reported by Adamson et al. [6] and Rhoden and small [7], Krishnamurthy et al. [11], Gibson and Waring [19], Hago and Oman [13], Hago et al. [20] and Abdelbagi [14].

4. Conclusion and Recommendation

Based on the findings of the present study it could be concluded that although most studied growth and yield parameters were not significantly affected by chemical and organic fertilizers, but it was observed that slight insignificant increasing in these parameters under fertilizer treated plants, and hence it recommended that further studies related to types and levels of fertilizer should be carried out.

Acknowledgment

The authors wish to thanks Faculty of Agriculture, Omdurman Islamic University, Elobaied Research Station, Industrial Research and Consultancies Centre, the Environmental and Natural Resources Research Institute for grateful assistance and supporting our research.

References

[1] Muslihatin W, Daesusi R and Kuncoro E P 2015 Influence of photoperiod to red roselle (Hibiscus sabdariffa L.) calyx phytochemical content J. Chem. Pharm. Res. 7 154–7
Cobley L S 1975 An Introduction of the Botany of Tropical Crops 2nd ed., (London: Longmans Greens) pp. 91-92
Van Damme P and Viaene N 1987 Optimal proportions between N, S and P; and between K, Ca and Mg in the fertilization of roselle (Hibiscus sabdariffa L.) Trop. Agric. 64 279-282
Nwezor W O, Udo E J and Sobulo R A 1989 Fertility states and productivity of acid sand In: Acid Sands of Southern Nigeria Monograph No.1 Soil Science Society of Nigeria pp: 65-73
Duke J A and Alche A A 1984 Proximate Analysis in Christie B R (Ed) The Handbook of Plant Science in Agriculture (Boca Raton, FL: Crop Press, Inc.)
Adamson W C, Long F L and Bagby M O 1979 Effect of nitrogen fertilization on yield, composition and quality of kenaf Agron. J. 7111-14
Rhoden E G and Small T 1991 Production and nitrogen uptake of roselle Hort. Sci. 26 pp:738.
Rhoden E G, David P and Small T 1993 Effect of nitrogen nutrition on roselle in Janick J and Simon J E (eds) New Crops (New York: Wiley) pp. 583-584
Atta S, Sarr B, Bakasso Y, Diallo A B, Lona I, Saadou M, and Glew R H 2010 Roselle (Hibiscus sabdariffa var Sabdariffa) yield and yield components in response to nitrogen fertilization in Nigeria Indian J. Agr. Res. 44 (2) 96-103
Himalah N, Baktir A and Purkan P 2019 Exploration of Cellulolytic Microorganism as A Biocatalyst Candidate for Liquid Fertilizer Production IOP Conf. Ser. Earth Environ. Sci. 217
Krishnamurthy N, Hunsign G, Rudaradhy M and Singlachar M A 1994 Effect of nitrogen level and spacing regime in physiological parameters and biomass production Mestra Curr. Res. University of Agricultural Sciences Bangalore 23 102-103
Gibson T A and Waring S A 1994 The soil fertility effects of leguminous ley pastures in northeast Thailand I. Effects on the growth of roselle (Hibiscus sabdariffa cv. Altissima) and cassava (Manihot esculenta) Field Crops Res. 39 119-127
Hago T E M and Osman B M 1999 Effect of nitrogen and phosphorus on some quality attributes of Roselle (Hibiscus sabdariffa var. sabdariffa L.) under irrigation Univ.of Khartoum J. of Agr. Sci.7 (2)16-24
Abdelbagi A A 2001 Effect of Nitrogen, Phosphorous, Sulfur and Season on Growth, Yield and Quality of Two Roselle (Hibiscus sabdariffa var Sabdariffa) Genotype. Ph.D Thesis Department of Agronomy Faculty of Agriculture, University of Khartoum, Khartoum, Sudan
Abu-Elseoud M A A, Abd El-Sabour M F and Omer E A 1997 Productivity of roselle (Hibiscus Sabdariffa L.) plant as affected by organic waste compost addition to sandy soil Bull of the National Research Center Cairo 22 (4) 495-505
Gad N 2011 Productivity of Roselle (Hibiscus sabdariffa L.) plant as affected by cobalt and organic fertilizer J. of App. Sci. Res. 7 (12) 1785-1792
Billington F H 1943 Compost for Garden Plot, or Thousand Acre Farm Practical Guide To Modern Methods (London: Russell Square)
Gomez K A and Gomez A A 1984 Statistical analysis of factorial system In: Statistical Procedures for Agricultural Research (New York: John Wailey and Sons)
Waring S A and Gibson T A 1994 The soil fertility effects of leguminous ley pastures in northeast Thailand: II. Effects on soil physical and chemical parameters Field Crops Res. 39 129-137
Hago T E M, Abdelbagi A A and Ahmed F E 2002 Response of Roselle (Hibiscus sabdariffa var sabdariffa) to nitrogen, phosphorus and sulfur under summer and winter sowing Univ. of Khartoum J. Agr. Sci. 10 (1) 40-52