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ROSELLE (*HIBISCUS SABDARIFFA* L.) YIELD AND YIELD COMPONENTS IN RESPONSE TO NITROGEN FERTILIZATION IN NIGER

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ABSTRACT

Although nitrogen application could improve growth and yield of roselle, fertilizer recommendations for Niger are lacking. The objective of this study was to evaluate the effects of two treatments of nitrogen (N1=50 kg N,ha^{-1} and N2=100 kg N.ha^{-1}) on yields and yield components in three ecotypes of Roselle (A3, A7 and A9). An increase in nitrogen was associated with an increase in leaf yield in every ecotype. However, there was no significant difference in yields between N1 and N2. Compared with the control plants (N0), the increase was about 181% for A3, 70% for A7 and 95% for A9 at N2. This level of nitrogen significantly decreased seed yield by 30% for A3 and 48%, respectively for A7 and A9. Nitrogen treatment had no effect on calyx yield which was approximately identical for the three ecotype (420 kg ha^{-1}). With the exception of the number of branches/plant, yield components were not affected by nitrogen application. Therefore, N1 could be considered as the optimum fertilization for leaf yield.

Key words: Roselle, Nitrogen, Yield, Ecotypes, Niger.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.), a member of the Malvaceae family, is a tropical annual shrub cultivated in subtropical and tropical zones (Kosakowska *et al., 2005*). Roselle plays a considerable economic role, even though it is largely underutilized and underappreciated. The plant is valued for its stem fibers, edible calyces, leaves and seeds that have nutritional and medicinal uses (D'Heureux and Badrie, 2004). The leaves are consumed as a green vegetable (spinach) while the stems are a source of pulp for the paper industry (Small and Rhoden, 1991). Roselle calyces are used in producing drinks, jellies, sauces, chutneys, wines, preserves and are also a source of natural food colorants such as anthocyanin (Delgado-Vargas and Parcedes-Lopez, 2003). Consequently, the calyces have received industrial attention internationally (Egharevba and Law-Ogbomo, 2007). The drink is readily available and is an inexpensive source of vitamin C (Babajide *et al.*, 2004). Moreover, Roselle is one of the most popular folk medicinal plants due to its colored calyces which are also used in the pharmaceutical and cosmetic industries (Ibrahim and Hussein, 2006). In addition, the seeds are subjected to a solid-state fermentation process which produces a meat substitute condiment known as dawadawa-botso in Niger, bi-kalga in Central Burkina and datou in Mali (Bengaly *et al.*, 2001). In

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rural populations, this condiment is mostly used in sauces accompanying cereals and pastas.

In Niger, roselle is grown traditionally, without chemical fertilization. Although Roselle reacts favorably to N application by growing more vigorously (Van Damme and Viaene, 1987), little is known about the fertilizer requirements of *Hibiscus sabdariffa*, in Niger where fertilizer recommendation guidelines are lacking. The objective of this investigation was to determine the effects of nitrogen fertilization on yield and yield components for three Roselle ecotypes.

MATERIAL AND METHODS

Growing Conditions

The experiment was conducted under rainfall conditions during the 2006 rainy season at the experimental station at Agrhymet Regional Centre in Niamey, Niger (latitude 13° 29' N, longitude 2° 10' E, and altitude 222 m). Daily temperature varied from 20.3 to 27.4°C for the minimum and 28.8 to 37.6 °C for the maximum during the growing season. The variation of air humidity was from 29.4 to 69.5 % for the minimum and 74.7 to 97 % for the maximum. The incoming radiation varied from 4,94 to 25,97 $MJ.m^{-2}.j^{-1}$. The accumulated rainfall was 395 mm. The soil of the experimental site was neutral (pH = 7.4), sandy, with approximately 0.20 % of C, 0.162% of total N and 0.0479% of P (Ndiaye, 2002).

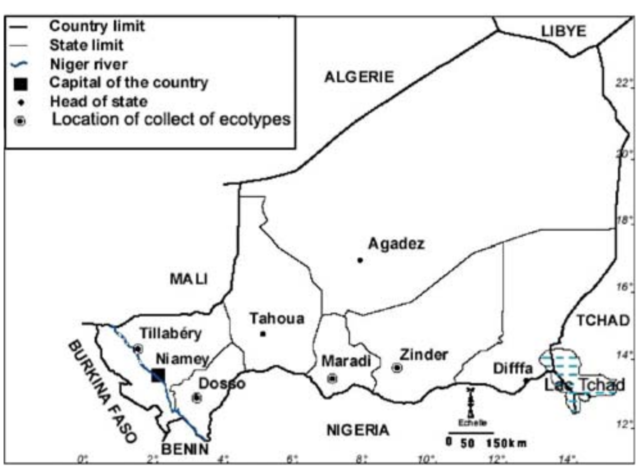

Fig. 1: Map of the Republic of Niger and locations where ecotype of Roselle were collected.

Plant Material: Three roselle ecotypes (A3, A7 and A9) field tested, were collected by Professor Saadou Mahamane and Dr Youkoubou Bakasso, members of the research team, between November and December 2000 in the south sahelian zone of Niger (Fig. 1). Ecotypes A3 and A9 were collected in the area around the town of Dosso, and A7 in the area around the town of Maradi. Ecotypes A3 and A7 belong to the botanical type called "Waré" in the Hausa dialet which is cultivated mainly for its developed calyx. The calyx was dark red for A3 and black for A7. Ecotype A9 had a rose colored calyx and belongs to the botanical type "Yakua" which has a medium-sized calyx and is cultivated mainly for its leaves and seeds.

Experimental design: Three nitrogen fertilization levels and three ecotypes constituted the two variables studied in a split plot arranged in a completely randomized block with four replications.

The experimental design consisted of a split plot with four replicates and two variables. Plots were subjected to the following nitrogen fertilization levels: 0 kg $N.ha^{-1}$ (N0), 50 kg $N.ha^{-1}$ (N1), and 100 kg $N.ha^{-1}$ (N2) using A3, A7 and A9 ecotypes.

The nitrogen variable was in the main plot while the ecotype variable was in the second plot. The plot consisted of rows 10 m long and 6 m wide. Each plot contained 6 rows of plants with 1 m apart between rows. The distance between two consecutive blocks was 2 m.

Soil preparation and sowing: Since the soil of the experimental site was sandy, its capacity of water retention was low and and its nutrient leaching very high. Consequently, 10 tons/ha of organic matter was applied in order to improve its capacity for water retention. In addition, NPK (15-15-15) fertilizer was added before sowing at the level of N2. The fertilizers were incorporated into soil using a plough. Ten Roselle seeds were hand sown in each hole on july 14, 2006 with an intra-row spacing of 1 m. Then 22 days later, the crop was thinned to two plants per hole.

Nitrogen treatment: Urea containing 46% N was used as source of nitrogen. The full dose of nitrogen was applied at 4 weeks after sowing (WAS) for 50 kg $N.ha^{-1}$ level of fertilizer (N1). For the N2 level, the dose was halved and applied at 4 and 8 WAS. Nitrogen was applied in a band on one side of Roselle rows, at 5 cm from the plant.

Measurements: After plant emergence, the leaf area index (LAI) of all ecotypes of each plot were measured using an LAI 2000 (Plant Canopy Analyser, Li-cor, Lincoln, Nebraska, USA) (Breda, 2003). Measurements were carried out twice a week until maturity as follows: one measurement of incoming radiation above the canopy and four measurements of the fraction of diffuse incident radiation passing through plant canopy.

After harvest, the following measurements were performed on five individual plants randomly selected from the middle of the center rows of each plot: total number of branches per plant, fruits per plant, and seeds per fruit; plant collar diameter; full plant height; leaf, seed and calyx yields; and weight per hundred-seeds.

The harvest index of the calyx was calculated by dividing the calyx weight by the total plant weight above ground (seeds + calyces +leaves + stem). The harvest index of seeds (ratio between seed weight and total plant weight above ground) was also calculated.

Statistical analysis: Statistical analysis was performed using the GenStat software (version 7.0). Differences between means were compared using the procedure of analysis of variance (ANOVA) and the Newman Keuls test at the 0.05 probability level.

RESULTS AND DISCUSSION

Table 1 shows the leaf, calyx and seed yields of the 3 ecotypes as a function of their respective nitrogen fertilizer levels. The results demonstrate a variation of leaf yield among ecotypes. For the control treatment N0 (0 kg $N.ha^{-1}$), leaf yield varied from 679 kg. ha^{-1} for ecotype A3 to 1079 $kg.ha^{-1}$ for A9. Ecotype A7 was intermediate. There were significant differences in leaf yield among all three levels of nitrogen fertilizer for all three ecotypes (Table 1). Therefore, the application of nitrogen significantly increased leaf yield. Maximum leaf yields of 1909 $kg.ha^{-1}$, 1562 $kg.ha^{-1}$ and 2105 $kg.ha^{-1}$ were obtained respectively for A3, A7 and A9 with N2. Plants maintained at N1 were intermediate, respectively 1548 $kg.ha^{-1}$, 1295 $kg.ha^{-1}$ and 1855 $kg.ha^{-1}$. When N1 was applied, leaf yield was higher for ecotype A3 (128% of the control) than A7 and A9 (Table 1).

Table 1: Leaf, seed, and calyx yields ($kg.ha^{-1}$) of three Roselle ecotypes as affected by nitrogen supply at harvest.

Level of fertilizer use ($kg N.ha^{-1}$)	Leaves			Seeds			Calyces		
	A3	A7	A9	A3	A7	A9	A3	A7	A9
0	679b†	921b	1079b	660a	512a	755a	442	411	424
50	1548ab	1295ab	1855ab	575b	294b	609b	413	355	490
100	1909a	1562a	2105a	464c	264b	394c	427	431	385

†: Data in the same column with the same letter (s) are not significantly different at 0.05 probability level.

Table 2: Harvest index of calyces and seeds at harvest, and maximum of leaf area index (LAI max) of three Roselle ecotypes as affected by nitrogen supply.

Level of fertilizer use ($kg N.ha^{-1}$)	LAI max ($cm^2.cm^{-2}$)			Seed Harvest Index			Calyx Harvest Index		
	A3	A7	A9	A3	A7	A9	A3	A7	A9
0	3.93b†	4.50b	3.96c	18.73a	12.80a	16.77a	12.68a	10.00a	9.32a
50	6.94a	6.97a	5.51b	10.07b	5.85b	7.69b	7.23b	6.29b	6.03ab
100	6.84a	6.14a	7.08a	6.81b	5.09b	5.42b	6.31b	8.02b	5.20b

†: Data in the same column with the same letter (s) are not significantly different at 0.05 probability level.

Table 3: Effect of nitrogen supply on stem diameter, plant height and yield components of three Roselle ecotypes at harvest.

Level of fertilizer use (kg N.ha^{-1})	Stem diameter (cm)			Plant height (m)			Weight of 100 seeds (g)		
	A3	A7	A9	A3	A7	A9	A3	A7	A9
0	1.77b†	2.28b	1.89b	1.49	1.34	1.71	3.68	3.67	3.36
50	2.54a	2.87a	2.70a	1.61	1.44	1.92	3.66	3.88	3.07
100	2.63a	2.60ab	2.73a	1.67	1.37	1.81	3.71	3.73	2.89
Levels of fertilizer (kg N.ha^{-1})	Number of fruits/plant			Number of seeds/fruit			Number of branches/plant		
	A3	A7	A9	A3	A7	A9	A3	A7	A9
0	38.02	41.20	59.78	23.92	21.99	16.01	17.08b	12.43b	22.52b
50	36.63	31.15	78.17	22.47	17.84	15.41	26.36ab	23.88a	42.97a
100	34.40	41.32	65.87	22.43	19.92	13.46	30.54a	21.89a	41.85a

†: Data in the same column with the same letter (s) are not significantly different at 0.05 probability level.

There was a significant variation in seed yields between the ecotypes. At the N0, seed yield varied from 512 kg N.ha^{-1} for ecotype A3 to 755 N.ha^{-1} for A9. Ecotype A7 was intermediate, with 660 kg.ha^{-1}. There was also a significant difference in seed yields between different levels of nitrogen fertilizer for all ecotypes (Table 1). The increased amounts of nitrogen significantly decreased seed yield for all ecotypes. However, this decrease was more significant at the N1 level. For A7, the decrease of seed yield at N1 was higher (43% of the control) than those of the other ecotypes which were 13% and 19% of the control, respectively, for A3 and A9. Thereafter seed yield remained relatively constant for A7 at the N2 level of fertilizer. In contrast, for ecotypes A3 and A9, plants under N2 had significantly lower seed yields, 464 kg. ha^{-1} and 394 kg. ha^{-1} than those under N1, respectively, 575 kg.ha^{-1} and 609 kg .ha^{-1}. Moreover, N2 decreased seed yield in the same proportion, around 50% of the control, for A3 and A9.

There was no variation in calyx yield among the three ecotypes. For control plants, the average calyx yield was 420 kg. ha^{-1} (Table 1). For N0, the harvest index of calyces varied from 9.32 for ecotype A9 to 12.7 for A3 (Table 2). While seed harvest indexes varied from 12.8 to 18,7 respectively for ecotype A7 and A3.

Nitrogen fertilization had significant effects on both calyx and seed harvest indices for all ecotypes. Indeed, supplying N1 and N2 significantly decreased seed and calyx harvest indices relative to the control (Table 2). At N1 level of fertilizer, the harvest index of seeds was 10.1 for ecotype A3, 5.9 for A7 and 7.7 for A9. Harvest indices of calyces were respectively 7.2, 6.3 and 6.0. With the exception of ecotype A3 which had the highest harvest index of seeds at N1, the variation between harvest indices of seeds and calyces was small among ecotypes and between N1 and N2 (Table 2).

According to plant growth and the treatments, the LAI value ranged from 0.5 cm^2.cm^{-2} to 1.0 cm^2.cm^{-2} between 13 and 48 days after sowing (Fig. 2). Thereafter LAI increased markedly for all ecotypes, with a maximum range between 62 and 83 days after sowing for all treatments. Then LAI decreased to reach values between 1.0 cm^2.cm^{-2} and 2.0 cm^2. cm^{-2}, three weeks later. For any given level of fertilizer, the maximum of LAI value varied only slightly between the three ecotypes (Table 2). For example, at 0 kg N.ha^{-1} level of fertilizer, the maximum LAI was 3.9 cm^2. cm^{-2} for A3, 4.5 cm^2.cm^{-2} for A7 and 4,0 cm^2.cm^{-2} for A9. For ecotype A9, the increased use of nitrogen significantly increased the maximum value of LAI, 5.5 cm^2. cm^{-2} and 7.1 cm^2.cm^{-2} at N1 and N2, respectively. In the same way, nitrogen supply has increased the maximum LAI value for A3 and A7, although no significant differences were recorded between N1 and N2.

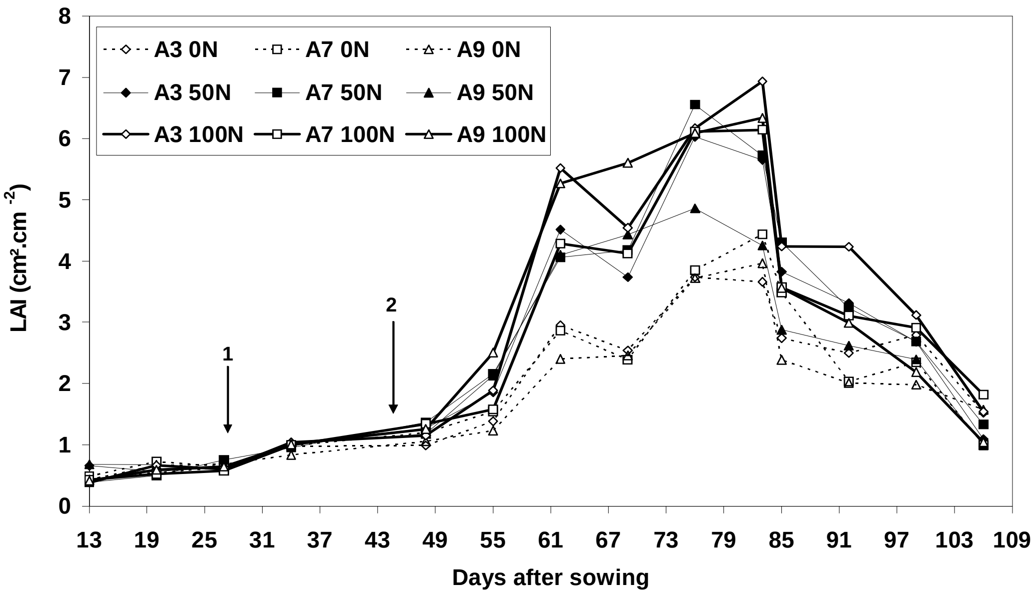

Figure 2: Change in the leaf area index (LAI) of three Roselle ecotypes (A3, A7 and A9) as affected by nitrogen supply (0N= 0 kg N.ha^{-1}, 50N = 50 kg N.ha^{-1} and 100N= 100 kg N.ha^{-1}).

1 : Application of 50 kg N.ha^{-1} respectively for 50 kg N.ha^{-1} and 100 kg N.ha^{-1} levels
2 : Application of 50 kg N.ha^{-1} for 100 kg N.ha^{-1} levels.

The stem diameter (Table 3) varied greatly among ecotypes at 0 kg N.ha^{-1}, from 1.8 cm (A3) to 2.3 cm (A7). Nitrogen usage significantly increased the stem diameter for all ecotypes of Roselle; however, there was no significant difference between N1 and N2. For N1 or N2, the stem diameter was about 2.7 cm for all ecotypes.

Access to nitrogen has significantly increased the number of branches/plant for all ecotypes, but no significant difference was observed between N1 and N2. The number of branches/plant was two-fold higher for these treatments for A7 (23.0 branches/plant) and A9 (42.0 branches/plant) compared to the control, 12.4 and 22.5 branches/plant, respectively (Table 3). However for A3, the effect of nitrogen supply on the number of branches/plant significant, was less important, 26.4 branches/plant at N1, 30.5 branches/plant at N2, whereas 17.0 branches/plant was recorded for the control.

Plant height was not significantly affected by the extent of nitrogen fertilization (Table 3). For the control treatment, plant height varied from 1.3 m (A7) to 1.7 m (A9).

There was also no significant difference in the number of fruits/plant given a variation of nitrogen (Table 3). But variations were recorded among ecotypes. Indeed, the number of fruits/plant was higher for ecotype A9, 59.8 fruits/plant, 78.2 fruits/plant and 65.9 fruits/plant, respectively at N0, N1 and N2. The corresponding values for A3 were 38.0 fruits/plant, 36.6 fruits/plant and 34.4 fruits/plant.

On the other hand, nitrogen did not significantly affect the weight per hundred seeds or the number of seeds/fruit of both ecotypes (Table 3). The average weight per hundred seeds varied from 3.7 g for ecotypes A3 and A7 to 3.0 g for A9.

In Niger, leaf, seed, and calyx yields of *Hisbiscus sabdariffa* L. are very low (Seyni, 2005) compared to those reported elsewhere (Ibrahim and Husein, 2006). These low yields are mainly due to the low potential of cultivated varieties and the fact that farmers do not use chemical fertilizers. The application of nitrogen could contribute improve the growth and yield of Roselle and hence improve farmer's income and alleviate poverty.

Our results indicate that increased nitrogen fertilization has significantly increased leaf yields of all ecotypes. Moreover, nitrogen also increased LAI, although no significant differences were recorded between N1 and N2. These results confirm those previously reported (Hago and Osman, 1999; Hago *et al.*, 2002). The increase of leaf yield resulted from a significant increase in the number of branches/ plant (Table 3). Indeed, the number of branches/ plant doubled when the amount of nitrogen increased from N0 to N2. This result confirmed those of Hago *et al.* (2002) who found that the number of branches/ plant increased with the level of nitrogen fertilizer at N1 and N2. Similarly, Egharevba and Law-Ogbomo (2007) found that the application of N2 increased the number of branches. But when the application of nitrogen was further increased (150 and 200 kg N.ha^{-1}), branching was reduced. Egharevba and Law-Ogbomo, 2007 made a similar observation.

The access to nitrogen had no effect on plant height for all ecotypes as has been reported in previous studies (Rhoden *et al.*, 1993; Egharevba and Law-Ogbomo, 2007). However, Okosun *et al.* (2006) found in a semi-arid agro ecological zone of Nigeria, an increase in plant height at 40 kg N.ha^{-1}. Selim *et al.* (1993) also reported a significant positive response of the plant height of Roselle to nitrogen. This was indicative of not only the importance of plant height, but also to its association with vegetative growth. The plant height of 1.67 m for ecotype A3, 1.37 m for A7 and 1.81 m for A9 at N2 observed in our study is in agreement with the findings of Egharevba and Law-Ogbomo (2007) who reported 1.50 m at 60 kg N.ha^{-1}. Moreover Selim *et al.* (1993) reported plant height of 1.60 m at the highest nitrogen level (180 kg N.ha^{-1}). Plant height was also found to vary markedly with seasonal variations while no variation was recorded among varieties within years (Kumar *et al.,* 1985).

Nitrogen fertilization also had a significant effect on plant-stem diameter, although no difference was observed between N1 and N2. These results were similar to those reported by Aliyu and Olarewaju. (1996) who showed that the beneficial effects of N and P was associated with larger stem diameter.

However, the application of nitrogen under N1 or N2 did not significantly affect certain yield components such as the weight per hundred seeds, the number of fruits/plant and the number of seeds/ fruit. Okosun *et al.* (2006) reported that at lower nitrogen levels (20 kg N.ha^{-1}), nitrogen did increase the number of fruits/pod and the number of seeds/ fruit.

Calyx yields did not differ significantly among ecotypes. The average calyx yield was about 420 kg.ha^{-1}, which was higher than values previously reported for the same ecotypes (Seyni, 2005), indicating the great effect of seasonal variations in calyce yield. Ottai *et al.* (2006) demonstrated that Roselle cultivars responded to different environmental changes. They showed that for Roselle, the dried and fresh calyx yields per plant were more sensitive to environmental changes than other characters such as plant height, number of branches/plant, number of bolls/plant.

In the present, N1 and N2 did not significantly improve the calyx yield (Table 1) o the calyx harvest index (Table 2). However in another investigation, N1 and N2 did significantly increase the calyx yield (Hago *et al.*, 2002). Egharevba and Law-Ogbomo (2007) reported no variation in calyx dry weight among 100, 150 and 200 kg N.ha^{-1}. However, Okosun *et al (*2006) found under lower rates of fertilization (20 kg N.ha^{-1}), that the effect of nitrogen on calyx yield varied according to the.

The increase in nitrogen application negatively affected seed yield of Roselle and consequently decreased the seed harvest index (Table 2). Indeed, for ecotype A3, seed yields decreased from 660 kg.ha^{-1} for the control to 464 kg.ha^{-1} at N2. For ecotypes A7 and A9, the seed yield was nearly halved to 264 and 394 kg.ha^{-1} respectively at the N2 level of application. Small and Rhoden (1991) also reported that nitrogen application increased leaf yield but not seed yield, indicating that the nutrients for seed production may not be the same as those needed for leave or calyx production.

Our results showed that increased nitrogen significantly increases leaf yield; however ,no significant difference was recorded between N1 and N2. The highest leaf yield (2105 kg.ha^{-1}) was obtained for ecotype A9 at N2. However, while nitrogen application decreased seed yield, it did not affect the calyx yield. Except for the number of branches/plant, yield components were also not affected by the application of nitrogen. Therefore, N1 kg N.ha^{-1} could be considered as the optimum level of nitrogen fertilization for leaf yield. However, for seed and calyx production, further research is needed to determine the effect of lower nitrogen levels.

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