Influence of apical cutting on growth parameters of Roselle (*Hibiscus sabdariffa* L.) in two agro-climatic zones of Niger

ABSTRACT

Improving roselle yield and production, particularly in light of climate change and variability, remains challenging and constantly urges for the modification of agro-techniques. One such modification that has proven successful in boosting yield of many vegetable crops in recent years is the adaptation of the apex cutting technique, especially in unfavorable agro-climatic circumstances where traditional methods are not plausible. This study was to assess the effect of cutting the main stem apical bud on roselle growth parameters and determine the optimal stage of apex cutting. The experiment was conducted in a split plot experimental device in randomized blocks with four (4) repetitions at Tara/Gaya and Tarna/Maradi. Two factors were studied, six (6) roselle ecotypes and four (4) levels of apex cuttings viz. C0 (uncunt plants as a control); C1 (20 days after sowing (DAS)); C2 (30 DAS); and C3 (40 DAS). The findings showed that apex cutting significantly affected all the morphological parameters evaluated. Apex cutting significantly reduced the total plant height and the number of primary branches per plant. Furthermore, significant increases were observed in the diameter and the number of secondary branches per plant for the six ecotypes. Moreover, the optimal time-point for obtaining the best collar diameter and secondary branches per plant was found to be between cut 1 (20 DAS) and cut 2 (30 DAS).

Keywords: *Hibiscus sabdariffa*, ecotypes, growth, cutting stage, apex, Niger

1. INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is a vegetable plant of the Malvaceae family, cultivated in Niger for its leaves, calyxes and seeds [1-3], which are exploited for their multiple medicinal properties and food products [4-6]. In terms of food, the leaves are widely consumed in Niger as vegetables in sauce, and the calyxes used for the manufacture of refreshing drinks locally called bissap [5, 6]. The seeds are used to make soumbala which is widely consumed by the rural population [7]. It is used in the preparation of dishes to enhance the taste of sauces accompanying dishes based on cereals such as rice, millet, sorghum, corn, etc. [5, 8]. Medicinally, roselle is exploited for its many secondary metabolites with therapeutic properties [9, 10]. Roselle also has laxative, purgative, cardio-regulatory, diuretic, sedative, and toning properties [11, 12].

Despite its multiple potentials, roselle production fails to meet local consumption demand. This situation is not only linked to low yields, but also to the techniques of agricultural production which remain predominantly traditional [13]. Indeed, it is cultivated in association with cereals and generally on the edges of farms without any amendments [14, 5]. One of the possible solutions to improve the production of this crop is to afford mineral and organic fertilizers [15]. However, fertilizers are not accessible most of the smallholder farmers because of the high costs on the one hand, but also the lack of means of transporting manure especially in fields far from the village on the other hand [16]. In this context, improving roselle yield and production, particularly in light of climate change and variability, remains challenging and constantly urges for the modification of agro-techniques [5]. One such modification that has proven successful in boosting yield of many vegetable crops in recent years is the adaptation of the apex cutting technique, especially in unfavorable agro-climatic circumstances where traditional methods are not plausible. The stimulating properties of this technique on growth and yield parameters have been previously reported by several authors including Aliyu *et al.* on okra (*Abelmoschus esculentus* L.) [17], Koefender *et al.* on marigold (*Calendula officinalis* L.) [18], Mardhiana *et al.* on cucumber (*Cucumis sativus* L.) [19], Shilpa and Priyanka on okra (*Abelmoschus esculentus* L.) [20], and Kaka-Kiari *et al.* on roselle (*Hibiscus sabdariffa* L.) [21].

The overall objective of this study was to assess the effect of cutting the main stem apical bud on growth parameters and determine the optimal stage of stem apex cutting.

2. MATERIAL AND METHODS

2.1. Experimental site and plant material

The trials were conducted in two experimental stations of the National Institute of Agronomic Research of Niger (INRAN) during the rainy season 2017. The station of Tara/Gaya (11°53’N and 3°19’E) has a North-Sudanian climate while that of Tarna/Maradi (13°27’N and 7°06’E) has a Sahelian climate. The total rainfall recorded during the experiment (from July to October) was 589.04 mm at Tara and 245.60 mm at Tarna within 37 days and 22 days, respectively (Figure 1).

The plant material consisted of six (6) ecotypes of Roselle (*Hibiscus sabdariffa* L. var sabdariffa) [22]. The seeds were supplied from the Laboratory for Management and Development of Biodiversity in the Sahel of the Faculty of Science and Technology of the University of Niamey. The characteristics of the studied ecotypes are presented in Table 1. These ecotypes were chosen for their leaf, calyx and seed production and their adaptability.

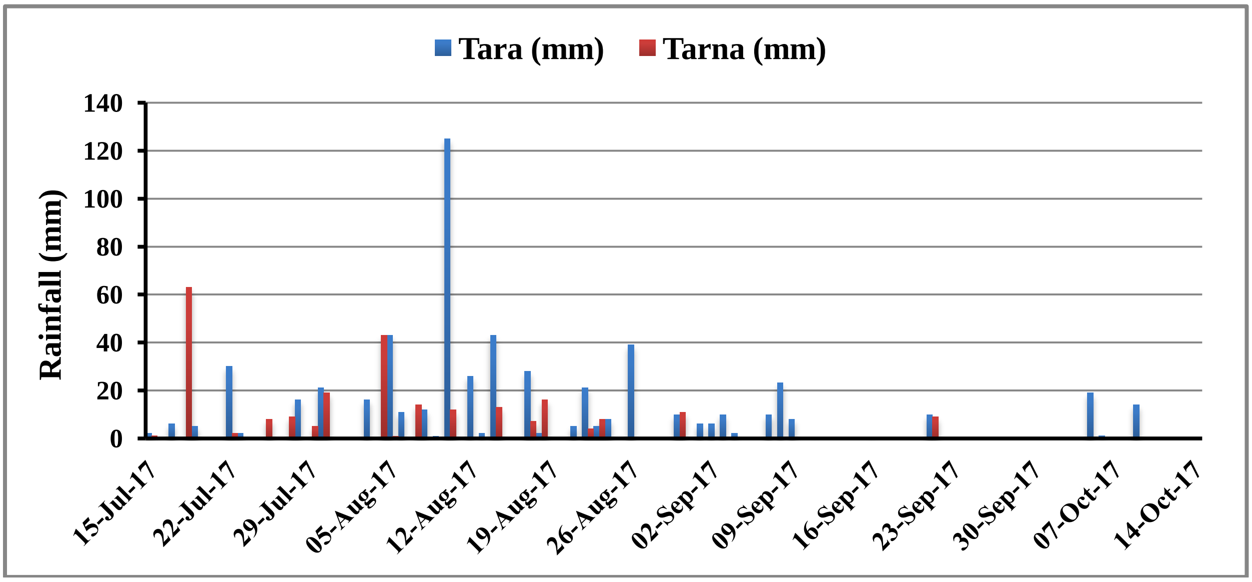

Figure 1: Weekly distribution of rainfall in Tara (in blue) and Tarna (in red) in 2017

Table 1: Region of origin, botanical types and characteristics of the different ecotypes studied

Ecotypes	Region of origin	Botanical type	Color of calyx	Color of stems	Characteristics
E1	Tillabéry	Hairy Yakua	White striped	Red	Seeds and leaves
E4	Zinder	Waré	white	Red	White calyx
E5	Maradi	Waré	Light	Red	Red calyx
E6	Maradi	Yakua	White	White	Leaves and seeds
E7	Maradi	Waré	Green	Green	Green calyx
E8	Dosso	Waré	Black	Black	Black calyx

Source: Bakasso et *al.* (2008).

2.2. Experimental design and crop management

The experimental device used was a split plot in randomized blocks comprising 24 treatments with 4 replications and 96 elementary plots. Each elementary plot measured 6 m in length and 5 m in width. The spacing was 1 m between pockets and 1.5 m between rows for a plant density of 15000 plants/ha. The sowing (at a rate of 5 seeds per pocket) was carried out on July 20th and July 28th at Tarna and Tara, respectively. Thinning to two plants per sowing pocket was carried out on the 10th day after sowing (DAS) and to one plant on the 18th DAS in the two study sites.

2.3. Apex cutting methods

The apex of the stem was cut at three different time-points: 20, 30 and 40 days after sowing (DAS). Uncut plants of each ecotype were used as a control for each treatment. The method consisted of cutting the tip of the main stem apex at about 5 cm at each specified time-point using pruning shears (Figures 2 and 3). However, it must be taken into account that nothing will grow above the cut, only the parts that have remained below the cut will develop and become the new main parts (Figure 4). The different levels of apical bud cuts were:

- Cut 0 (C0): no apex cut (normal growth);
- Cut 1 (C1): apex cut of the main stem at 20 DAS (when the plants have an average height of about 13 cm);
- Cut 2 (C2): apex cut of the main stem at 30 DAS (when the plants have an average height of about 25 cm);
- Cut 3 (C3): apex cut of the main stem at 40 DAS (when the plants have an average height of about 45 cm).

Figure 2(A-B): Apex cutting technique with pruning shears

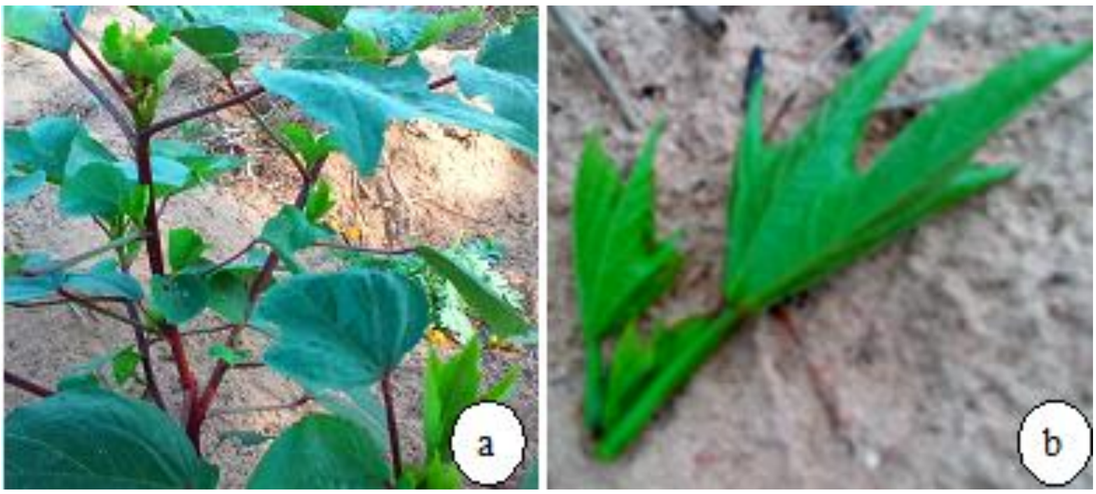

Figure 3: (a) Emergence of secondary branches on an uncut plant, (b) End of apex cutting

Figure 4(A-B): Emergence of new secondary branches on cut plants a week later

2.4. Data collection

All evaluated parameters were measured and counted at maturity in a 7.5 m^2 yield square corresponding to the six central plants. They were:

- ✓ The length of the stem, evaluated using a graduated ruler by measuring the height from the soil surface to the last leaf fork;
- ✓ The collar diameter , measured using an electronic caliper at the level of the plant collar;
- ✓ The primary and secondary branches counted at harvest.

2.5. Statistical Analysis

Data were entered into the Excel spreadsheet and statistical analyzes were performed using GenStat version 12.1.0.3278 (Copyright 2009, VSN International Ltd). Analysis of variance (ANOVA) was performed to assess the effects of apex cut, ecotype and their interactions. The Student Newman Keuls test at the significance level of 5% was used for means comparisons.

3. RESULTS

3.1. Collar Diameter (mm)

Table 2 presents the results of the effect of the different apex cuts on the collar diameter. The results show that in Tara, the cutting of the apex of the main stem results in a significant increase in the diameter of the plant compared to the control. However, the greatest average increase (26%) was observed with early cut (20 DAS). Late cuts (30 and 40 DAS) resulted in a similar increase in the average diameter collar of the plant (12%). In Tarna, 20 and 30 DAS cuts displayed a similar increase (10%) in the collar diameter. This increase was lower than that of Tara (1%) while the late cut (40 DAS) did not show any significant effects.

Differential responses about apex cuttings were observed among ecotypes across sites (Table 2). Apex cutting had no significant effect on the diameter of the E6 ecotype at the two sites and the E7 and E8 ecotypes at Tarna. However, at both sites, cutting the apex at 20 DAS significantly increased the diameter of E1, E4 and E5 ecotypes. This increase was particularly greater at Tara (23%, 31%, and 30%, respectively) as compared to Tarna (12%, 14%, and

15%, respectively). For the E1 ecotype, at Tara, the increase in collar diameter was similar for the three cutting time-points (20, 30 and 40 DAS). At Tarna, the increase is identical for the E1 and E4 ecotypes at 20 and 30 DAS.

Table 2: Effect of apex cuts of roselle stem on collar diameter (mm) in Tara and Tarna

	Tara				Tarna			
Ecotypes	C0	C1	C2	C3	C0	C1	C2	C3
E1	14.75b	18.20a	16.29ab	15.84ab	21.01b	23.62a	22.35ab	20.69b
E4	13.08b	17.20a	15.63b	15.53a	20.06b	22.77a	21.51ab	20.58b
E5	13.75b	17.93a	15.38b	14.96b	29.50c	34.06a	31.80b	29.74c
E6	14.92a	17.25a	16.69a	15.68a	27.77a	30.09a	27.55a	26.29a
E7	14.17c	18.66a	15.91b	16.68b	21.15a	23.72a	23.70a	21.49a
E8	14.11b	17.79a	15.67ab	16.22ab	23.99a	27.69a	26.05a	24.51a
Means ±	**14.13c**	**17.84a**	**15.93b**	**15.82b**	**23.92c**	**26.99a**	**25.49b**	**23.88c**
SD	**0.67**	**0.56**	**0.48**	**0.59**	**3.92**	**4.47**	**3.82**	**3.66**
Ecotypes	ns	ns	ns	ns	***	***	***	***
Cuts	***	***	***	***	***	***	***	***

C0: control; C1, C2, and C3: cuts at 20, 30 and 40 DAS, respectively. Values with the same letter (s) in the same row are not significantly different at the p <0.05 level; ***: significant at the probability threshold of 0.001 and ns: not significant (p> 0.05).

3.2. Total Plant Height (m)

The results show that at the two sites, all the three apex cutting dates of the Roselle plant resulted in a significant reduction in the average plant height compared to the control. No significant differences were observed between early cuts (20 and 30 DAS) and the late cut (40 DAS) for the plant height. For all ecotypes, cutting the apex of the main stem results in a significant reduction in plant height at the two sites. This reduction is similar for the three cuts for the E1 and E7 ecotypes at the two sites as well as for E6 and E8 at Tara. It is similar for the cuts made at the 20 DAS and 30 DAS stages for the E4 and E5 ecotypes at the two sites and E6 at Tarna (Table 3).

Table 3: Effect of apex cuts of roselle stem on total plant height (m) at Tara and Tarna

	Tara				Tarna			
Ecotypes	C0	C1	C2	C3	C0	C1	C2	C3
E1	1.44a	0.93b	0.88b	0.96b	1.19a	0.97b	0.98b	1.03b
E4	1.29a	0.91bc	0.88c	0.98b	1.12a	0.94c	0.91c	1.03b
E5	1.38a	0.85c	0.85c	1.07b	1.46a	1.05c	1.04c	1.20b
E6	1.46a	0.89b	0.93b	1.00b	1.35a	1.05c	1.05c	1.20b
E7	1.27a	0.90b	0.88b	0.96b	1.18a	0.95b	0.98b	1.00b
E8	1.28a	0.93b	0.93b	0.98b	1.31a	1.01c	1.00c	1.15b
Means ±	**1.35a**	**0.90c**	**0.90c**	**0.99b**	**1.27a**	**1.00c**	**1.00c**	**1.10b**
SD	**0.08**	**0.02**	**0.03**	**0.04**	**0.12**	**0.04**	**0.05**	**0.09**
Ecotypes	ns	ns	ns	ns	***	***	***	***
Cuts	***	***	***	***	***	***	***	***

C0: control; C1, C2, and C3: cuts at 20, 30 and 40 DAS, respectively. Values with the same letter (s) in the same row are not significantly different at the p <0.05 level; ***: significant at the probability threshold of 0.001 and ns: not significant (p> 0.05).

3.3. Primary Branches Number/Plant

At both trial sites, all of the apex cuttings resulted in a reduction in the number of primary branches of the plant compared to the control (Table 4). This reduction is similar but greater (41% at Tara and 65% at Tarna) for the two early cuts (20 DAS and 30 DAS) compared to the late cut (31% and 28%, respectively).

The apex cutting results in a decrease in the number of primary branches for all ecotypes at the two sites (Table 4). For all ecotypes in Tarna, the 20 DAS and 30 DAS cuts caused the strongest decreases in the number of primary branches. This reduction was 67% for E1, E4, E5 and E6, and 60% for E7 and E8. There is no significant difference in primary branches number among E4, E5, and E8 under the three different cuts at Tara. Similarly, no significant differences were observed for the two early cuts (20 DAS and 30 DAS) with E1, E6 and E7.

Table: 4: roselle stem on primary branches number per plant in Tara and Tarna

	Tara				Tarna			
Ecotypes	C0	C1	C2	C3	C0	C1	C2	C3
E1	15.40a	7.83c	8.67bc	10.42b	31.25a	10.33c	11.08c	21.17b
E4	13.98a	7.75b	8.08b	9.50b	30.58a	9.25c	10.17c	22.42b
E5	14.63a	8.42b	8.17b	10.33b	33.67a	11.25c	11.75c	23.67b
E6	15.64a	7.45c	7.58c	10.25b	30.33a	12.33c	8.75c	21.17b
E7	15.26a	7.33c	7.83c	10.92b	26.83a	9.08c	10.17c	20.83b
E8	14.59a	7.25b	7.83b	9.58b	26.42a	10.33c	10.33c	20.00b
Means ±	**14.92a**	**7.67c**	**8.03c**	**10.17b**	**29.85a**	**10.43c**	**10.37c**	**21.54b**
SD	**0.62**	**0.43**	**0.37**	**0.53**	**2.76**	**1.22**	**1.01**	**1.30**
Ecotypes	ns	ns	ns	ns	*	*	*	*
Cuts	***	***	***	***	***	***	***	***

C0: control; C1, C2, and C3: cuts at 20, 30 and 40 DAS, respectively. Values with the same letter (s) in the same row are not significantly different at the p <0.05 level; *, ***: significant at the probability threshold of 0.05, 0.001 and ns: not significant (p> 0.05).

3.4. Secondary Branches Number/Plant

The results in Table 5 show that apex cutting induced a significant increase in the number of secondary branches of the plant compared to the control at both sites. At Tara, the largest increase (31%) was observed for the early cut (20 DAS). Cuttings at 30 and 40 DAS led to a similar increase of 21%. At Tarna, significant but similar increases in the number of secondary branches were observed for cut 1 and cut 2 (33%). No significant effect was observed with cut 3.

In terms of ecotypes, cutting the apex had no effect on the number of secondary branches of the plant for E6 and E8 at Tara. In addition, for the other ecotypes, the increase in the number of secondary branches was similar for the three cutting stages. The largest increases (35%) were recorded with E1 and E8 ecotypes and the smallest with E4 and E5. At Tarna, the increases in the number of secondary branches were similar for the cuts made at the 20 and 30 DAS stages for the E1, E4, E6, E7, and E8 ecotypes (Table 5). The cut at 20 DAS achieved the greatest number of secondary branches (increase of 69%), followed by 30 DAS (44%).

The highest increase (56%) was recorded for E8 and the smallest (17%) for E6. The E1, E4 and E7 ecotypes are intermediate with a similar increase in the number of secondary branches by 30%. At the E5 ecotype, the cut at 20 DAS gave the best number of secondary branches (increase of 69%), followed by that at 30 DAS (44%). The 40 DAS cut also resulted in a significant increase in the number of branches, although lower than that of the early cut (17%).

Table 5: Effect of apex cuts of roselle stem on secondary branches number per plant in Tara and Tarna

	Tara				Tarna			
Ecotypes	C0	C1	C2	C3	C0	C1	C2	C3
E1	62.47b	89.74a	78.24a	87.07a	128.1b	171.7a	160.6a	125.2b
E4	54.08b	74.90a	62.71ab	64.42ab	71.50b	95.08a	88.92a	70.17b
E5	54.72b	74.85a	65.04ab	68.70a	68.50d	116.08a	98.67b	80.17c
E6	75.54a	94.26a	87.33a	82.02a	143.2b	172.9a	161.3ab	140.5b
E7	60.35a	68.15a	69.12a	66.83a	66.75b	90.92a	82.08a	64.92b
E8	51.86b	69.92a	70.50a	66.58a	64.42b	101.67a	99.92a	70.25b
Means ±	**59.84c**	**78.64a**	**72.16b**	**72.60b**	**90.4b**	**124.7a**	**115.2a**	**91.9b**
SD	**8.68**	**10.78**	**9.15**	**9.48**	**37.76**	**37.82**	**36.00**	**32.48**
Ecotypes	***	***	***	***	***	***	***	***
Cuts	***	***	***	***	***	***	***	***

C0: control; C1, C2, and C3: cuts at 20, 30 and 40 DAS, respectively. Values with the same letter (s) in the same row are not significantly different at the $p < 0.05$ level; ***: significant at the probability threshold of 0.001 and ns: not significant ($p > 0.05$).

4. DISCUSSION

This study showed that the apex cuts of the main stem of Roselle induced significant increases in the diameter and the number of secondary branches per plant for the 6 ecotypes evaluated. However, apex cutting reduced the total plant height and the number of primary branches per plant. Similar studies by [23, 24] have shown that cutting apex of the main stem causes a considerable reduction in plant height and an increase in the number of secondary branches depending on the stages of apex cutting. These authors also hypothesized that these variations could be attributed to the suppression of apical dominance resulting in the cessation of auxin synthesis due to the apex cutting of the main stem. Furthermore, [25] reported that apex cutting is the most promising approach for secondary branches production in vegetable crops. These findings also showed that apex cutting reduced the number of primary branches per plant by 50% compared to the control. This could be attributed to the plant growth processes disruption caused by apex cutting. This could be also explained by the delay in plant growth (for a certain period) caused by apex cutting before the emergence of new shoots [19]. This result is in line with that of [26] Olasantan on the squash (*Cucurbita maxima* Duch. Ex. Lam.), who reported significant reduction in primary branches production following apex cutting.

This physiological phenomenon is associated to the synthesis of ethylene, which is caused by the stress induced by apex cutting. According to [27], ethylene production is regulated by environmental factors such as injury, cold, water stress, decreased O_2; as well as endogenous factors: auxin, cytokinins, and abscissic acid. Indeed, auxin and cytokinins are important protagonists for the production of ethylene and they act with a certain synergy [28, 29]. The ethylene and auxin levels are usually self-adjusting to achieve balance. Ethylene is widely distributed in plants and its quantity varies greatly over time and space [30]. In most plants, ethylene has a repressive effect on cell growth. This growth inhibition would result from an alteration of the orientation of the microtubules and microfibrils of the cells, thus resulting in a reduction in elongation [31]. In addition, auxin and cytokinins are essential elements for rhizogenesis and the development of aerial organs [32].

The number of secondary branches increased considerably with apex cutting. This increase could be explained by the suppression of apical dominance, which results in the cessation of auxin synthesis due to the cutting of the main stem apex [33]. The apex contains a plant hormone (auxin) responsible for apical dominance, which limits the growth of the lateral branches [21, 34]. When the apex is cut, the plant redistributes this hormone to the side branches. This auxin, originally intended for apex growth will drive back to the secondary stems thereby promoting their development [19]. Therefore, each secondary stem will behave like a main stem by developing a main apex. Underneath each secondary stem, will emerge many other secondary branches and capsules, thereby increasing yields [29]. The analysis of these results revealed the existence of a variation of certain parameters of the ecotypes according to the sites. This variability could be related to the differences in soils and climatic conditions of the two sites [2].

5. CONCLUSION

This study evaluated the effects of apex cutting on the growth of sorrel crop. The results showed that apex cutting significantly affected all the morphological traits evaluated. Apex cutting significantly reduced the total plant height and the number of primary branches per plant. However, significant increases were observed in the collar diameter and the number of secondary branches per plant for the six ecotypes evaluated. The optimal time-point for achieving the best collar diameter and secondary branches per plant was found to be between cut 1 (20 DAS) and cut 2 (30 DAS). Upcoming investigations will deeply assess the effects of apex cutting and validate these preliminary findings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bakasso Y, Zaman-Allah M, Mariac C, Billot C, Vigouroux Y, Zongo JD, and Saadou M. Genetic diversity and population structure in a collection of roselle (*Hibiscus sabdariffa* L.) from Niger. Plant Genetic Resources: Characterization and Utilization. 2013; 1-8. doi:10.1017/S1479262113000531.

2. Kaka-Kiari BK, Moussa M, Inoussa MM, Abasse AT, Atta S, et Bakasso Y. Effet d'un apport de Di-Ammonium Phosphate sur les paramètres agromorphologiques des écotypes d'oseille de Guinée (*Hibiscus sabdariffa* L.) dans deux zones agro-climatiques du Niger. Int. J. Biol. Chem. Sci. 2019a; 13(3): 1596-1612, ISSN 1997-342X.

3. Kaka-Kiari BK, AK Toudou Daouda, MM Inoussa, M Moussa, S Atta, Bakasso Y. 2021. Effet de NPK (15-15-15) sur la production des écotypes d'oseille de Guinée (*Hibiscus sabdariffa* L.) au Niger. Rev. Mar. Sci. Agron. Vét. 2021; 9(4) (Décembre 2021) 717-721. (Reçu le 05/03/2021; Accepté le 18/04/2021).

4. Hassane, HS. Etude de la variabilité du rendement de dix écotypes d'oseille (*Hibiscus sabdariffa*). Mémoire d'Ingénieur des Techniques Agricoles. Université Abdou Moumouni. Niamey. 2005; 47p.

5. Bakasso Y. Ressources génétiques des roselles (*Hibiscus sabdariffa* L.) du Niger : Evaluations agro-morphologiques et génétique. Thèse de doctorat, Université Abdou Moumouni. Niamey. 2010; 102p.

6. Atta S, Sarr B, Diallo AB, Bakasso Y, Issaka L, and Saâdou M. Nutrients composition of calyces and seeds of three Roselle (*Hibiscus sabdariffa* L.) ecotypes from Niger. African Journal of Biotechnology. 2013; Vol. 12 (26), 4174-4178.

7. Parkouda C, Diawara B, and Ouoba LII. Technology and physicochemical characteristics of Bikalga, alkaline fermented seeds of Hibiscus sabdariffa. Afr J Biotechnol. 2008; 7(7): 916-922.

8. Abdou, SR, Oumarou DH, Alio SA, Bakasso Y, et Abdourahamane, B. Caractérisation biochimique et microbiologique de Soumbala de néré (*Parkia biglobosa*) et d'oseille de Guinée (*Hibiscus sabdariffa*) produits au Niger. European Scientific Journal. 2020; Vol.16, No.3 ISSN: 1857-7881, (Print) e-ISSN, 743. Doi:10.19044/esj.2020.v16n3p224.

9. Lépengué AN, Mouaragadja I, Chérif M, M'batchi B, Aké S. Effet du chlorure de sodium (NaCl) sur la croissance de la roselle au Gabon. Afrique Science. 2009; (5)3: 97-110.

10. Atta S, Seyni HH, Bakasso Y, Sarr B, Issaka L, and Saâdou M. Yield character variability in Roselle (*Hibiscus sabdariffa* L.). African Journal of Agricultural Research. 2011; Vol. 6(6), pp. 1371-1377.

11. Olaniran OA, Alao FO & Adebayo TA. Control of foliage pests of Roselle (*Hibiscus sabdariffa* L.) using plant extracts of *Tephrosia vogelii* and *Azardiractha indica* in Ogbomoso, Nigeria. Transnational Journal of Science and Technology. 2013; 3(6):51-62.

12. Ognalaga M, Odjogui, P. I. O., Lekambou, J. M., Poligui, R. N. (2015). Effet des écumes à cannes a sucre, de la poudre et du compost à base de *Chromolaena odorata* (L.) King R.M. & H.E. Rob sur la croissance de l'oseille de Guinée (*Hibiscus sabdariffa* L.). Int. J. Biol. Chem. Sci., 9(5): 2507-2519.

13. Hien NA. Etude comparée de deux systèmes de culture (pluvial et irrigue) de la roselle (*Hibiscus sabdariffa* L.) dans la province du IOBA: évaluation du potentiel de production en calices. Mémoire d'ingéniorat, Institut Du Développement Rural. Université Polytechnique De Bobo-Dioulasso. 2012; 62p.

14. Aliou AB. Effet d'un apport de fertilisation minérale sur la sévérité de *Macrophomina phaseolina* de l'oseille (*Hibiscus sabdariffa* L). Mémoire de fin d'études, Centre Régional AGRHYMET, Niamey. 2009; 48p.

15. Caroline DD. Impact de pratiques de gestion de fertilité sur les rendements en mil dans le Fakara (Niger). Travail de fin d'études de bio ingénieur. Université de Louvain. 2006 ; 214p.

16. Traoré S, Bagayoko M, Coulibaly BS, Coulibaly A. Amélioration de la gestion de la fertilité des sols et celle des cultures dans les zones sahéliennes de l'Afrique de l'Ouest: une condition sine qua none pour l'augmentation de la productivité et de la durabilité des systèmes de culture à base de mil. 2004; 25p.

17. Aliyu U, Sukuni M and Abubakar L. Effect of pruning on growth and fresh fruit yield of okra (*Abelmoschus esculentus* L. (MOENCH) IN SOKOTO, NIGERIA, Journal of Global Biosciences. 2015; Volume 4, Number 7, 2015, pp. 2636-2640.

18. Koefender J, Schoffel A, Golle DP, Manfio CE, Dambróz APB, Horn RC. Pruning of the main stem of Marigold: effect on capitulate yield. Horticultura Brasileira. 2017; 35: 425-427. DOI - http://dx.doi.org/10.1590/S0102-053620170318.

19. Mardhiana, Ankardiansyah PP, Muh. Adiwena, Kartina, Dwi S, Rizza W, Anas M. Effects of pruning on growth and yield of cucumber (*Cucumis sativus*) Mercy variety in The acid soil of North Kalimantan, Indonesia Cell Biology & Development. 2017; Volume 1, Number 1, June 2017 E-ISSN: 2580-4499 Pages: 13-17.

20. Shilpa and Priyanka B. Effect of Plant Architecture on Seed Yield and Quality of Okra [*Abelmoschus esculentus* (L.) Moench]-A Review. Int.J.Curr.Microbiol.App.Sci. 2018; 7(02): 3794-3802.

21. Kaka-Kiari BK, Mamadou-Chetima MB, A. Moussa A, Abdou Habou MK, Atta S, Mahamane A and Bakasso Y. Effect of Apical Cutting on Roselle (*Hibiscus sabdariffa* L.) Production in Niger. Asian Journal of Biochemistry, Genetics and Molecular Biology. 2022; 12(2):7-16; Article no.AJBGMB.89140 ISSN: 2582-3698. DOI: 10.9734/AJBGMB/2022/v12i230288

22. Bakasso Y, Saadou M, Zongo JD and Baidou-Forson F. Analysis of agromorphological variability of *Hibiscus sabdariffa* L. in Niger. 2011; Ann. Sci Agron. Benin; 11: 21-33.

23. Ghosh A, Chikara J, Chaudhary D. Diminution of economic yield as affected by pruning and chemical manipulation of *Jatropha curcas* L. Biomass and Bioenergy. 2011; 35(3): 1021-1029.

24. Olasantan FO & Salau AW. Effect of pruning on growth, leaf yield and pod yields of okra (*Abelmoschus esculentus* (L.) Moench). Journal of Agricultural Science. 2008; 146(01): 93-102.

25. Kabir A. Effect of branch pruning on plant growth, fruit and seed yield okra, (*Abelmoschus esculentus*) cultiva (NHAe 47-4 and LD88- 1). Research project

submitted to Crop Production Department, Federal University of Technology, Minna, Niger State. 2010; 18.

26. Olasantan FO. Apical shoot harvest affects growth and apical shoot and fruit yields of pumpkin (*Cucurbita maxima* Duch. Ex. Lam.). Journal of Vegetable Science. 2007; 12: 73-87.

27. Stepanova AN, Yun J, Robles LM, Novak O, He W, Guo H, Ljung K, and Alonso JM. «The *Arabidopsis* YUCCA1 flavin monooxygenase functions in the indole-3-pyruvic acid branch of auxin biosynthesis». The Plant Cell. 2011; 3:3961-3973.

28. Gao X, Nagawa S, Wang G, and Yang Z. Cell polarity signaling: focus on polar auxin transport. Mol. Plant. 2008; 21, 899-909.

29. Ibrahim SM, Hassanullah M, & Arif B. The Effects of Different Concentrations and Combinations of Growth Regulators on the Callus Formation of Potato (*Solanum tubrosum*) Explants. Current Research Journal of Biological Sciences. 2011; 3: 499-503.

30. Todjro CGH, Ahanhanzo C, Dangou, JS, Houedjissin SS, et Agbangla C. Effets de différentes combinaisons hormonales sur l'organogenèse *in vitro* de quelques cultivars locaux et variétés améliorées de *Manihot esculenta* Crantz (manioc-*Euphorbiaceae)* cultivées au Bénin. Int. J. Biol. Chem. Sci. 2012; 6(4): 1593-1607.

31. Leblond-Castaing J. Caractérisation de l'interaction des protéines IMA/MIF2 et CSN5 au niveau moléculaire et physiologique. Thèse de doctorat présenté à l'Université de Bordeaux 1. 2011; 344p.

32. Ahanhanzo C, Agbangla C, Agassounon DTM, Cacaï G, Dramane K. Etude comparative de l'influence des régulateurs de croissance sur la morphogénèse (*in vitro*) de quelques variétés de *Manihot esculenta* Crantz (manioc-euphorbiaceae) du Bénin. 2008; Rev. CAMES-Série A, 07: 47-52.

33. Ahmed M and Oladiran JA. Effect of Stem Cutting and Variety on Shoot Development and Seed Yield of Jute Mallow (*Corchorus olitorius* L.). Experimental Agriculture & Horticulture. 2012; Article ID:1929-0861-2012-12-3.

34. Gilbert B. La taille et la dominance apicale : Journée des producteurs en pépinière de l'IQDHO 1er février 2018, Drummondville. 2018; (M.Sc., agr. Conseiller en serriculture IQDHO, gbilodeau@iqdho.com.