

Effect of Apical Cutting on Roselle (*Hibiscus sabdariffa* L.) Production in Niger

**Kaka Kiari Boukar Kellou^{a*}, Mamadou Chetima Maina Boukar^a,
Alio Moussa Abdourazak^b, Abdou Habou Maman Kamal^a,
Atta Sanoussi^c, Mahamane Ali^{a,b} and Bakasso Yacoubou^b**

^a *Faculté des Sciences Agronomiques, Université de Diffa, BP 78, Diffa, Niger.*

^b *Faculté des Sciences et Techniques, Université Abdou Moumouni de Niamey, BP 10662, Niamey, Niger.*

^c *Département Formation et Recherche, Centre Régional AGRHYMET-CRA-AOS/CILSS, BP 11011, Niamey, Niger.*

Authors' contributions

This work was carried out in collaboration among all authors. Author KKBK designed the experiment, performed the statistical analysis and wrote the first draft of the manuscript. Authors MCMB, AHMK, AS, BY and MA managed the literature searches. Author AMA reviewed the manuscript. All authors read and approved the final version of the manuscript.

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ABSTRACT

Roselle (*Hibiscus sabdariffa* L.) plays a critical socioeconomic role in Sahelian populations (Niger, Burkina, Mali, Senegal...). During the 2017 rainy season, a field experiment was carried out in Tara/Gaya and Tarna/Maradi to study the effect of apex cutting on Roselle production. The experiment used a split-plot in randomized blocks of four (4) replications with ecotypes as the main plot factor and apex cuts as subplots. Three (3) levels of apex cut were used viz. C1 (20 days after sowing), C2 (30 days after sowing), and C3 (40 days after sowing). The results revealed that apex cutting increased leaf, calyx, and seed yields significantly ($P < 0.001$) in both study sites. This increase in yield (leaf, calyx, and seed) was roughly 15% and 10% in Tarna and Tara, respectively. The most beneficial cutting stage was between 20 and 30 days after sowing (DAS). This study, however, should be expanded to more agroclimatic zones to further assess the effect of apex cutting on Roselle productivity in Niger.

*Corresponding author: E-mail: boukar787@gmail.com, boukiari@yahoo.com;

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1. INTRODUCTION

Owing to its leaves, calyxes, and seeds, Roselle (*Hibiscus sabdariffa* L.) plays an important socioeconomic role in Sahelian populations (Niger, Burkina, Mali) [1,2]. It is cultivated in all the tropics, especially in Africa, Central America, India, and Malaysia [3].

It is well adapted to the Nigerien climate because it is widely and variously used in both rural and urban areas [1,4]. However, its yield is generally low due to poor fertilization and poor cultivation techniques [5]. Several studies relating to the supply of mineral fertilization have shown a significant effect on the productivity of this crop [2,6-9]. Nevertheless, because of the high cost of chemical fertilizers and farmers' low purchasing power, these are poorly implemented. The application of novel farming practices is one way to address this critical demand [10].

In addition, the use of these new cultivation technologies which are less expensive and easy to apply, such as the apex cut of the main stem, could be an alternative to improve the yield of Roselle. This practice can reduce the expenses linked to the use of chemical fertilizers. Previous studies have demonstrated that cutting the tip of the main stem of various cultivated crops increased the number of branches hence the final yield [11,12], especially in vegetable crops [13]. The objective of apex cutting is to remove the apical dominance, promote branching, regularize production and improve yields [12]. Furthermore, the apex contains a particular plant hormone (auxin) which causes apical dominance, while limiting the growth of other branches [13,14]. Therefore, cutting the apex of the plant stops auxin synthesis in the bud, which will cause the lateral branches to develop more effectively [12]. The main objective of this study was to determine the effect of apex cutting on Roselle's yield and its components.

2. MATERIALS AND METHODS

2.1 Study Area

The trials were conducted in open fields in two different experimental research stations of the

National Institute of Agronomic Research of Niger (Tara and Tarna), during the rainy season of 2017. The Tara/Gaya station, located at 310 km south-east of Niamey (11°53'N and 3°19'E) in the northern Sudan agro-climatic zone and Tarna/Maradi station (13°27'N and 7°06'E), located at 657 km East of the capital Niamey, in the Sahelian agro-climatic zone.

The cumulative precipitations during the experiments were 589.04 mm at Tara and 245.60 mm at Tarna. The average temperature was slightly higher at Tarna (29.20°C) compared to Tara (28.15°C) (Fig. 1). The average relative humidity was 78.14% at Tara and 67.19% at Tarna (Fig. 2) [4].

2.2 Plant Material

The plant material used in this study was Roselle ecotypes grown in Niger. These ecotypes were collected as part of the activities of the Research Laboratory in Management and Development of Biodiversity for the Sahel [15]. The origin, botanical types, and characteristics of these ecotypes are presented in Table 1.

2.3 Experimental Design

The experiment was carried out using a split-plot in randomized blocks with four (4) repetitions. Ecotypes in main plots and apex cuts in subplots. Each main plot, measuring 20 m x 6 m (120 m²) was subdivided into four elementary plots of 30 m² (6 m x 5 m) for a total of 96 experimental plots with each plot made up of 4 rows of 5 hills. Sowing was carried out at the rate of 5 seeds per pocket on July 20 in Tarna and July 28, 2017 in Tara. Spacings were 1.5 m between rows and 1 m between pockets.

2.4 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 from each ecotype were used as a control in each experimental plot. The method involves cutting the tip of the main stem at 5 cm at the vegetative stage, using pruning shears.

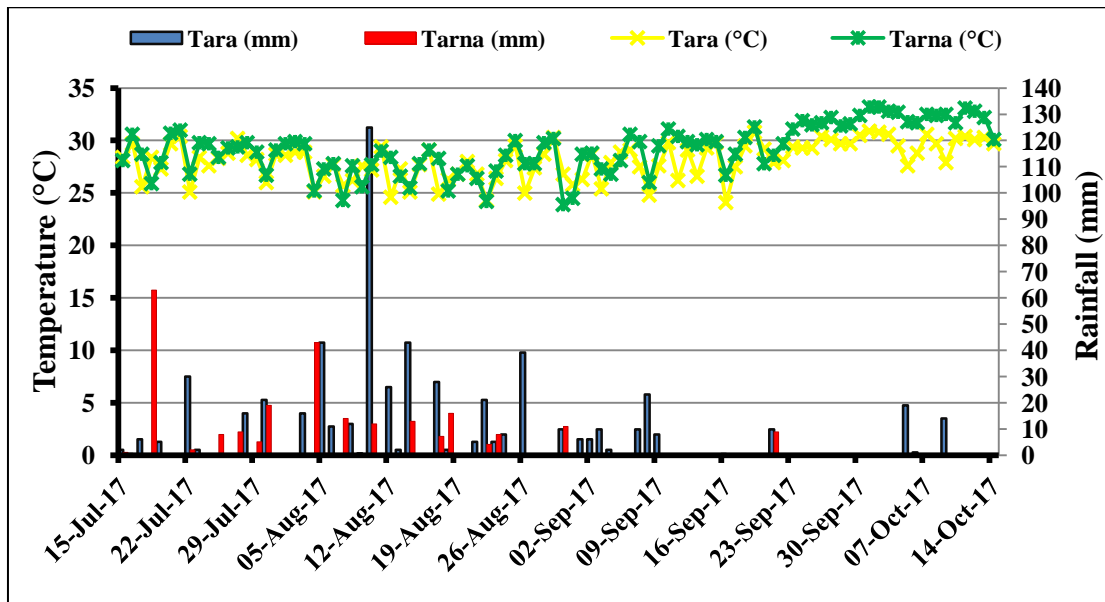


Fig. 1. Weekly distribution of rainfall and temperature in Tara and Tarna in 2017 [4]

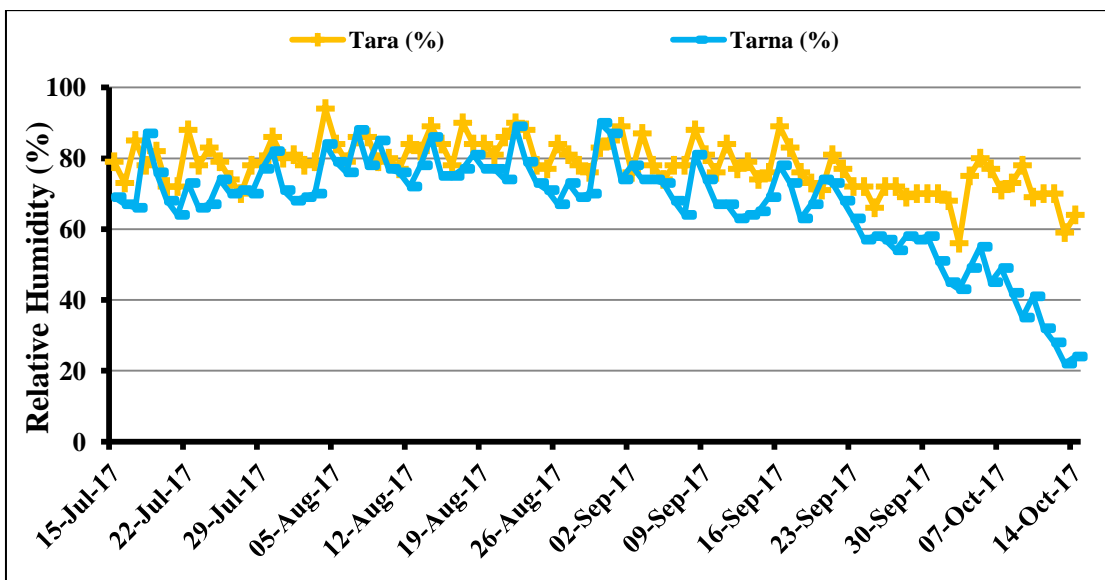


Fig. 2. Weekly distribution of relative humidity in Tara and Tarna in 2017 [4]

Table 1. Origin, botanical types and characteristics of the different ecotypes studied in Niger

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	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. [15].

Four (4) levels of apical bud cuts were applied to plants during development:

- ✓ **Cut 0 (C0):** no apex cut of the main stem was made to the plants (normal growth);
- ✓ **Cut 1 (C1):** the apex cut of the main stem was carried out at 20 days after sowing when the plants have an average height of about 13 cm;
- ✓ **Cut 2 (C2):** the apex cut of the main stem was carried out at 30 days after sowing when the plants have an average height of about 25 cm;
- ✓ **Cut 3 (C3):** the apex cut of the main stem was carried out at 40 days after sowing when the plants have an average height of about 45 cm.

2.5 Data Collection

The harvest was carried out on a 7.5 m² (3 m x 2.5 m) yield square formed from the 6 central plants at both sites. After separating and shade drying the different organs, the yields of leaves, calyxes, and seeds, as well as the weight of a hundred seeds, were weighed using an electronic balance.

2.6 Statistical Analysis

The GenStat software version 12.1.0.3278 (Copyright 2009, VSN International Ltd) was used for statistical analysis. Two-way factor analysis of variance (ANOVA) was also performed to assess the effect of apex cuts, ecotypes, and their interactions. The Student Newman Keuls test at the significance level of 5% was used for means comparison. Microsoft

Office Excel 2007 software was used to produce the graphics.

3. RESULTS

3.1 Number of Capsules/Plant

The apex cut of the main stem at 40 DAS (days after sowing) had no significant effect on the average number of capsules/plant at the two sites (Table 2). At Tara, the 20 DAS cut was the most effective with an average increase in the number of capsules of 27% compared to the control, followed by the 30 DAS cut (11%). In Tarna, the increase in the average number of capsules linked to cutting is even more significant. It is 56% and similar to cuts made at the 20 and 30 DAS.

At Tara, the cut of the apex of the main stem had no significant effect on the number of capsules/plant for the ecotypes E1 and E4. For the ecotypes E5 and E6, the cut at the 20 DAS stage were the most effective with an increase in the number of capsules respectively by 46% and 60% compared to the control. For E8, the cuts at 20 and 30 DAS caused a similar increase in the number of capsules/plant in the order of 31%. However, for E7, the 30 DAS cut was the most effective with an increase in the number of capsules per plant by 38%. In Tarna, the apex cuts at 20 and 30 DAS were the most effective with a similar increase in the number of capsules/plant, which is 40% for the E4 and E8 ecotypes, 28% for E7 and 20% for E1 and E6. For E5, the cut at 20 DAS was the most efficient (54%) followed by that at 30 DAS (24%) (Table 2).

Table 2. Effect of apex cuts of roselle stem on the number of capsules per plant in Tara and Tarna

Ecotypes	Tara				Tarna			
	C0	C1	C2	C3	C0	C1	C2	C3
E1	81.94a	91.68a	75.58a	69.68a	137.8b	175.7a	161.2ab	137.1b
E4	59.85a	69.51a	64.94a	57.47a	59.17b	85.08a	78.08a	61.42b
E5	57.19b	83.44a	60.44b	65.57b	74.83c	115.42a	100.33b	81.75c
E6	52.60c	83.83a	60.79bc	69.66b	70.25b	86.58a	81.17a	66.17b
E7	58.67b	67.79b	81.14a	62.96b	79.25b	103.67a	99.42a	83.42b
E8	52.50c	64.77ab	72.48a	57.85bc	63.92b	93.00a	84.42a	66.42b
Means ±	60.46c	76.84a	69.23b	63.86c	80.86b	109.9a	100.78a	82.71b
SD	10.96	10.89	8.48	5.44	28.81	34.18	31.04	28.11
Ecotypes	***	***	***	***	***	***	***	***
Cuts	***	***	***	***	***	***	***	***
Ecotypes x Cuts	***	***	***	***	ns	ns	ns	ns

C0: control; C1, C2 and C3: cut of the apex of the stem at 20, 30, and 40 days after sowing, respectively. Means followed by the same letter (s) in the same line are not significantly different at the 5% level. ***: significant at the probability threshold 0.001 and ns: not significant ($p > 0.05$). SD: Standard Deviation

3.2 Hundred Seeds Weight

Cutting did not show any significant effect ($P > 0.05$) on hundred seeds' weight at the two sites (Table 3). Similarly, the cutting effect was not significant for all the ecotypes at Tara as well as for the E1, E5, and E6 ecotypes at Tarna. However, for the E7 and E8 ecotypes, the cutting resulted in a significant reduction of the hundred seeds' weight at Tarna. The greatest reduction was recorded for early cutting (20 DAS). In contrast, for the E4 ecotype, the cutting of the apex at the 20 DAS resulted in a significant increase for the weight of hundred seeds (by 8%).

3.3 Leaf Yield / Hectare

At Tara, cutting of the stem at 20 DAS significantly increased the leaf yield by 10% as compared to the control (Table 4). Cutting at 30 DAS had no significant effect on leaf yield. At Tarna, cutting the apex of the main stem at 20 DAS and 30 DAS caused a similar and significant increase in leaf yield of 15%. The late cut at 40 DAS resulted in a reduction in leaf yield of 15% in Tara (Table 4).

The cuttings from the apex of the main stem did not affect on the leaf yield for E1 at the two sites as well as E4 and E6 at Tarna. In addition, the cuts made at 20 DAS and 30 DAS did not affect on the leaf yield of E7 at the two sites as well as the ecotypes E4, E5, and E6 and E8 at Tara. For all these ecotypes, the late cut (40 DAS) resulted in a significant and similar reduction in leaf yield, which is around 15%. At Tarna, cutting at the 20 DAS and 30 DAS significantly improved the leaf

yield of the E5 and E8 ecotypes. This improvement is similar for the two cuts and for the two ecotypes (17%). However, cutting at 40 DAS did not affect on the leaf yield of these ecotypes (Table 4).

3.4 Calyx Yield / Hectare

The average calyx yields at the two sites were affected significantly ($P < 0.001$) by the apex cut of the plant's main stem (Table 5). Tara's calyx yield was enhanced with the 20 DAS cutting (by 10%). The early (30 DAS) cut showed no significant effect, while the late (40 DAS) cut decreased calyx yield by 10%. At Tarna, cuts performed at 20 and 30 DAS resulted in a similar 15% increase of calyx yield.

The cut did not affect on the calyx yield of the E5 ecotype at Tara. Similarly, cuttings at the 20 and 30 DAS stages had little effect on calyx yield in the E4, E6, E7, and E8 ecotypes. However, the cut made at 40 DAS reduced the yield by 10%. At Tarna, a similar 15% improvement in calyx yield was recorded for cuts made at 20 and 30 DAS (Table 5).

Ecotypes responded differently to apex cutting. At Tara, the cut did not affect on the calyx yield of the E5 ecotype. Similarly, the cuts made at the 20 and 30 DAS stages did not affect the calyx yield of the E4, E6, E7, and E8 ecotypes. However, cutting at 40 DAS significantly reduced the leaf yield of these ecotypes. This reduction, which is similar for all these ecotypes, is around 10%. The E1 ecotype is the only one for which early cutting (20 DAS) resulted in a 20% increase in calyx yield at Tara (Table 5).

Table 3. Effect of apex cuts of roselle stem on the hundred seeds weight (g) at Tara and Tarna

Ecotypes	Tara				Tarna			
	C0	C1	C2	C3	C0	C1	C2	C3
E1	3.34aa	3.37a	3.23a	3.30a	3.45a	3.61a	3.73a	3.64a
E4	3.44a	3.40a	3.45a	3.45a	3.67b	3.95a	3.57b	3.70b
E5	3.38a	3.32a	3.34a	3.45a	3.68a	3.59a	3.77a	3.65a
E6	3.40a	3.32a	3.44a	3.37a	3.81a	3.58a	3.69a	3.58a
E7	3.39a	3.44a	3.42a	3.40a	3.86a	3.59b	3.58b	3.67ab
E8	3.60a	3.53a	3.64a	3.58a	3.99a	3.60b	3.76ab	3.83ab
Means ±	3.43a	3.40a	3.42a	3.43a	3.74a	3.65a	3.68a	3.68a
SD	0.09	0.08	0.13	0.09	0.18	0.14	0.08	0.08
Ecotypes	***	***	***	***	*	*	*	*
Cuts	ns	ns	ns	ns	ns	ns	ns	ns
Ecotypes x Cuts	ns	ns	ns	ns	***	***	***	***

C0: control; C1, C2 and C3: cut of the apex of the stem at 20, 30, and 40 days after sowing, respectively. Means followed by the same letter (s) in the same line are not significantly different at the 5% level. *, ***, significant at the 0.05 probability threshold; 0.05, 0.001 and ns: not significant ($p > 0.05$). SD: Standard Deviation

Table 4. Effect of apex cuts of roselle stem on leaf yields (kg ha⁻¹) in Tara and Tarna

Ecotypes	Tara				Tarna			
	C0	C1	C2	C3	C0	C1	C2	C3
E1	491.7a	547.7a	498.3a	425.0a	1097a	1318a	1263a	1075a
E4	425.8a	467.6a	427.5a	365.0b	799.4a	927.7a	907.8a	818.1a
E5	432.5a	472.5a	450.8a	372.5b	894.2c	1042.4a	1041.9ab	887.9c
E6	521.9a	558.3a	523.7a	438.3b	1274a	1478a	1398a	1339a
E7	432.5a	473.3a	432.5a	354.2b	937.1a	1014.8a	954.6a	836.3b
E8	430.0ab	461.7a	430.4ab	371.7b	931b	1087a	1083a	920b
Means ±	455.7b	496.9a	461.1b	387.8c	989b	1145a	1108a	979b
SD	40.76	43.81	40.73	34.86	169.63	209.22	188.00	198.41
Ecotypes	***	***	***	***	***	***	***	***
Coupes	***	***	***	***	***	***	***	***
Ecotypes x Cuts	ns	ns	ns	ns	ns	ns	ns	ns

C0: witness; C1, C2 and C3: cut of the apex of the stem at 20, 30, and 40 days after sowing, respectively. Means followed by the same letter (s) in the same line are not significantly different at the 5% level. ***: significant at the probability threshold of 0.001 and ns: not significant ($p > 0.05$). SD: Standard Deviation

In Tarna, early cutting also significantly improved the calyx yield for the E4 (20%), E5 (10%) and E6 (24%) ecotypes. For the E1 and E8 ecotypes, the cuts at stages 20 and 30 DAS resulted in a similar improvement in the calyx yield (30% for E1 and 15% for E8). No effect of the cut was observed for the E7 ecotype (Table 5).

3.5 Seed Yield / Hectare

The apex cut of the main stem resulted in a significant increase ($P < 0.001$) in seed yield at both experimental sites (Table 6). In Tara, cutting at 20 DAS improved the average seed yield by 10%. Cutting at 30 DAS had no effect on seed

yield. In Tarna, a similar improvement in seed yield (13%) was observed for the cuts made at the 20 and 30 DAS stages. The late cut (40 DAS) reduced the seed yield by 8% in Tara while it had no effect in Tarna.

The apex cut had no effect for the E6 and E7 ecotypes in Tara or the E5 ecotype in Tarna. At both sites, cutting the apex at the 20 DAS stage significantly increased the seed yield of the E1 ecotype. This increase is around 10% in Tara and 30% in Tarna. Furthermore, no significant difference was recorded between the cuts made at stages 20 and 30 DAS and the control for the ecotypes E4, E6, E7, and E8 at Tara.

Table 5. Effect of apex cuts of roselle stem on calyx yields (kg ha⁻¹) in Tara and Tarna

Ecotypes	Tara				Tarna			
	C0	C1	C2	C3	C0	C1	C2	C3
E1	238.3b	289.5a	253.1b	204.2c	251.8b	326.0a	325.7a	242.5b
E4	370.0ab	407.5a	395.1a	334.3b	713.7b	862.4a	835.0ab	716.4c
E5	372.9a	408.7a	404.3a	365.1a	694.1c	766.0a	760.4b	686.6c
E6	352.1ab	377.5a	357.1ab	318.2b	509.6b	633.8a	582.0ab	563.4ab
E7	399.5a	434.1a	393.2a	343.0b	642.7ab	698.8a	671.7ab	625.3b
E8	395.9ab	425.8a	393.1ab	351.2b	633.7b	724.1a	727.1a	656.7b
Means ±	354.8b	390.5a	366.0b	319.3c	574.3b	668.5a	650.3a	581.8
SD	59.70	53.17	57.64	58.56	173.31	184.18	180.34	174.39b
Ecotypes	***	***	***	***	***	***	***	***
Cuts	***	***	***	***	***	***	***	***
Ecotypes x Cuts	ns	ns	ns	ns	ns	ns	ns	ns

C0: witness; C1, C2 and C3: cut of the apex of the stem carried respectively at the stages of 20, 30 and 40 days after sowing. Means followed by the same letter (s) in the same row are not significantly different at the $p < 0.05$ level. ***: significant at the probability threshold 0.001 and ns: not significant ($p > 0.05$). SD: Standard Deviation

Table 6. Effect of apex cuts of roselle stem on seed yields (kg ha⁻¹) in Tara and Tarna

Ecotypes	Tara				Tarna			
	C0	C1	C2	C3	C0	C1	C2	C3
E1	520.6b	566.5a	512.5b	461.9c	793.3b	1014.2a	921.7ab	775.0b
E4	420.0ab	447.1a	421.7ab	380.0b	602.1b	691.9a	707.4a	608.1b
E5	410.8ab	450.3a	414.7ab	383.9b	627.0a	680.3a	677.5a	612.0a
E6	372.7a	429.1a	390.0a	363.0a	518.9b	603.1a	559.6ab	543.7ab
E7	405.4a	450.5a	394.3a	386.0a	555.4b	610.4a	573.2ab	528.7b
E8	404.7ab	445.8a	403.3ab	351.7b	576.3b	639.0a	642.6a	575.7b
Means ±	422.4b	464.9a	422.7b	387.8c	612.2b	706.5a	680.3a	607.2b
SD	50.70	50.41	45.56	38.69	96.26	154.95b	131.51	88.73
Ecotypes	***	***	***	***	***	***	***	***
Cuts	***	***	***	***	***	***	***	***
Ecotypes x Cuts	ns	ns	ns	ns	ns	ns	ns	ns

C0: witness; C1, C2 and C3: cut of the apex of the stem at 20, 30, and 40 days after sowing, respectively. Means followed by the same letter (s) in the same line are not significantly different at the 5% level. ***: significant at the probability threshold 0.001 and ns: not significant ($p > 0.05$). SD: Standard Deviation

In Tarna, the 20 DAS cut was the most effective for the E6 and E7 ecotypes as it increased the seed yield (by 16% for E6 and 10% for E7). Finally, in both sites, the late cutting of the apex carried out at 40 DAS showed no significant effect on the seed yield of all the ecotypes except of the E1 ecotype at Tarna, where a 10% decrease in seed yield was recorded (Table 6).

4. DISCUSSION

The results of this study showed that cutting the apex of the main stem promoted increases in the performance characteristics of Roselle ecotypes investigated. Compared to the control, this increase was about 10% at Tara against 15% at Tarna. This variation in yields could be explained by the significant increase in secondary branches, which might be responsible for the high yields observed from cut plants. According to Kabir [16], cutting apex produces the maximum amount of fruit and good quality. Similar results were revealed by [17] in tomato (*Solanum esculentum* L.), Slamet et al. [18] in Roselle (*Hibiscus sabdariffa* L.), Mardhiana et al. [19] in cucumber (*Cucumis sativus* L.), and Shilpa and Priyanka [20] in okra (*Abelmoschus esculentus* (L.) Moench).

The height of the apex showed a substantial effect on the number of capsules per plant [21,22,19] indicated that the number of capsules per plant was higher in cut plants of okra. In addition, Ahmed and Oladiran [13] have shown that the apex cut increases the number of pods per plant of okra (*Abelmoschus esculentus*) by 10 to 40%. Increases in leaf, seed, and calyx

yields, and also yield components, were also promoted by the apex cut of the main stem. In line results have been reported by Ahmed and Oladiran [13] in *Corchorus olitorius* in Nigeria. Furthermore, the weight of a hundred seeds was not affected by the different apex cuts, which agrees with the findings of Ahmed and Oladiran [13] in *Corchorus olitorius*. All these variations in yields (leaves, calyxes and seeds) could be explained by the significant increase in secondary branches, responsible for the high yields in cut plants. In addition, Cline et al. [11-13] have reported that cutting the apex of the main stem is one of the most important cultural practices for improving the yields of vegetable crops. Moreover, [23,24,18] stated that cutting the apex stimulates leaf production of Roselle as well as the development of photosynthetic activities.

Roselle's overall agronomic performance has greatly improved significantly as a result of stem apex cuts. This increment could be explained by the suppression of apical dominance, which occurred following the inhibition of auxin biosynthesis [13]. Auxin is responsible for apical dominance, which limits the growth of the lateral branches [25]. When the apex is cut, the plant redistributes this hormone to the side branches thereby promoting their development [19]. As a result, each secondary stem will act like the main stem by developing the main apex and underneath will start from the new secondary stems, producing several other secondary branches, afterward capsules, thus improving the final yield [12]. According to [26], auxin reacts in synergy with cytokinin, and participates in the

formation of new buds. These hormones are synthesized in the aerial parts of the plant (especially young leaves) and then migrate to the roots. This accumulation of auxin also causes root elongation along with, the emission of rootlets and secondary roots [27]. The cutting of the apex leads to an increase in cytokinin concentrations in the branches [29] probably due to an increase in transfer from the root system. Improved root system development was earlier stated to promote the efficient synthesis of plant-specific cytokinins [28].

This increment in cytokinins is also accompanied by an increase in leaf number [30]. This would boost photosynthetic activity and assimilation, responsible for the increase in yield [24].

Besides, apical cut involves another growth hormone (gibberellins), which is responsible for breaking dormant buds and promoting internodes elongation [26].

The late cut (at 40 DAS) reduced leaf yield (for E7 and E8), calyx yield (for E4 and E7), and seed yield (for E5 and E8) at both study sites. This could be attributed to the fact that at this stage (40 DAS), auxin and cytokinin biosynthesis declines, then stops due to leaf growth completion [32,26].

5. CONCLUSION

The apex cutting of the Roselle main stem significantly improved yield (leaf, calyx and seed) by 15% and 10% in Tarna and Tara, respectively. Cut 1 (at 20 DAS) yielded the highest results in Tara, whereas cut 1 and cut 2 (at 30 DAS) displayed the highest yields in Tarna. Collectively, the optimal apex cutting stage for Roselle crop can be deduced to be between 20 and 30 days after sowing. Therefore, when used appropriately, this farming technique can boost farmers' productivity while lowering costs associated with chemical fertilizer purchases. However, this investigation should be expanded to Niger's other climatic zones to better assess the effect of apex cutting on Roselle growth and productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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