

Effect of pinching date and potassium fertilizer rate on Growth and productivity of roselle (*Hibiscus sabdariffa*, L.) plant

ABSTRACT:

To enhance growth and productivity of roselle plant, two field experiments were done during the two consecutive summer season of 2019 and 2020 at Experimental Farm (Ghazala Farm), Faculty of Agriculture, Zagazig University, Egypt. This study included different pinching time treatments (after 4, 6, 8 and 12 weeks from sowing date) as the main factor and potassium fertilization rate (0.0, 25, 50 and 75 kg K₂O/ feddan) as sub-factor as well as their combinations to improve growth, yield, anthocyanin content and some chemical contents of *Hibiscus sabbdariffa* plant. Results could be summarized as follow: The longest roselle plants were recorded with the control treatment (pinched after 4 weeks from sowing date), whereas pinching after 12 weeks from sowing date increased number of branches/plant. Also, apical bud pinching after 12 weeks from sowing date recorded the highest number of fruits per plant, dry sepals yield/plant and per feddan. Delaying pinching date from 4 to 8 weeks gradually increased anthocyanin content. In addition, total chlorophyll content as well as total carbohydrates, total nitrogen, total phosphorus and potassium percentages were increased with delaying pinching date especially after 12 weeks, in most cases. Potassium fertilization rate at 75 kg per feddan recorded the highest values of growth, yield components and the chemical constituents with significant differences between this rate and the other rates under study. Generally, the combination treatment between pinching after 12 weeks from sowing date and 75 kg potassium fertilization rate had significant effect in most parameters compared to the other combination treatments during both seasons.

Key words: *Hibiscus sabdariffa*, pinching, potassium, growth, sepals yield, anthocyanin, chlorophyll

INTRODUCTION

Hibiscus sabdariffa (Roselle) is grown to achieve the red sepals or the fibers or double objectives. It belongs to the Malvaceae family, and is a biennial or annual plant planted in subtropical and tropical regions for its edible calyces, seeds, stem fibers, and leaves. Cultivation of this plant has been indicated throughout the part of Asia, Australia and America as well as throughout Africa (Cobley, 1968). Sepals are used as a raw material for making healthy drink, jelly, syrup, tea, vinegar and tea (Singh *et al.*, 2006). Egypt is counted as the country in which Roselle originated (Ismail *et al.*, 2008). It is known in various countries by different common names,

including karkade, roselle, red sorrel, razelle, sorrel, Indian sorrel, Jamaican sorrel, Guinea sorrel, Queensland jelly plant and sour-sour (**Mahadevan, 2009**).

Apical pinching as well, known as topping is one of the techniques utilized to improve plant growth and yield. Pinching includes the removal of the apical bud of a stem to promote development of lateral branches. This raises the potential fruit spots on the plant that way raising the fruit number produced per plant (**Marie et al., 2007**). Pinching supplies wider surface area for a bigger photosynthetic activity which in turn improves other growth parameters and yield components (**Kumar et al., 2014**). Furthermore, **Makinde et al. (2016)** indicated that pinching had an affirmative influence on the improvement of roselle growth and raised the calyx productivity compared with the unpinched plants (control).

Potassium (K) is the mineral nutrient demanded in the largest amount by plants. It is highly mobile within singular cells, within tissues and in long-stretch transport through the phloem and xylem (**Marschner, 1995**). K is an important element in plant metabolism, improving fats, protein and carbohydrates synthesis, promoting fresh produce quality and increasing crop yield (**Cakmak, 2005**). In addition, potassium is cementing plants performance to resist diseases and pests as well as K is acted as enzymes cofactor, including enzymes related to the active ingredients synthesis enable (**Hafsi et al., 2014**). The application of potassium fertilization impacted plant growth and yield of *Anthriscus cerefolium* (**Gendy et al., 2014**), *Thymus serpyllum* (**Pal et al., 2016**), *Allium cepa* (**Bekele, 2018**) and *Thymus vulgaris* (**Zrig et al., 2019**).

Therefore, the aim of this study was to evaluate the adequate apical bud pinching time and optimum potassium fertilization rate to obtain maximum vegetative growth, yield components with high anthocyanin content of roselle.

MATERIALS AND METHODS

This work was conducted to investigate the impact of different pinching times (after 4, 6, 8 and 12 weeks from sowing date), potassium fertilization rates (0.0, 25, 50 and 75 kg K₂O/feddan) and their combination treatments on plant growth, yield components, anthocyanin content and some chemical constituents of roselle plant (*Hibiscus sabdariffa*, L). Two field experiments were carried out at Experimental Farm (Ghazala Farm), Fac. Agric., Zagazig Univ., Egypt (30° 34' 07" N, 31° 34' 33" E) during the two consecutive summer seasons of 2019 and 2020. These treatments arranged in a split-plot design with 3 replicates. The main plots assigned to pinching date (four treatments) and the sub plots deviated to potassium fertilization rates (four treatments). The physical and chemical properties of the experimental soil site are presented in Table 1 according to **Chapman and Pratt (1978)**.

Table 1. Physical and chemical properties of experimental soil

Physical analysis				Soil texture							
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)								
56.36	9.26	17.62	16.76	Clay							
Chemical analysis											
pH	E.C. m.mohs/cm	Organic matter (%)	Soluble cations (meq./L)			Soluble anions (meq./L)		Available (ppm)			
			Mg ⁺⁺	Ca ⁺⁺	Na ⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ⁻	N	P	K
7.86	0.98	0.58	2.7	1.6	4.1	4.5	1.7	3.5	18	20	71

The experimental unit area was 14.40 m² (six ridges with 4 m length for each and 60 cm width). The distances between each of the two plants in the ridge was 50 cm. Two ridges were utilized for recording growth parameters and the others four ridges were utilized for determining roselle yield components and chemical determinations.

Roselle seeds (Deep red type) were obtained from Research Centre of Medicinal and Aromatic Plants, Dokky, Giza. Seeds were sown on 12th and 18th May during the 2019 and 2020 seasons and immediately irrigated. After 20 days from sowing date, seedlings were thinned to be one plant/hill. Roselle plants were fertilized with different potassium fertilization rates as potassium sulphate (48 %K₂O). All experimental units were fertilized with 200 kg calcium superphosphate (15.5 % P₂O₅) and 200 kg ammonium sulphate (20.5 % N) per feddan . During soil preparation phosphorus fertilizer was applied. In addition, potassium and nitrogen fertilizers were divided into four equal rates and were added to the soil at 30, 50, 70 and 90 days after sowing date.

Data Recorded

Plant growth parameters: plant height (cm), number of branches/plant, foliage dry weight (branches + leaves) / plant and root dry weight/plant were estimated at 120 days after sowing date by taking nine random roselle plants from each experimental unit.

Yield components: at harvesting stage (150-180 days after sowing), fruits number/plant and dry sepals yield per plant (g/plant) were determined as well as total dry sepals yield per feddan (kg/feddan) was calculated.

Chemical constituents: a sample of dry sepals was randomly taken from each treatment for chemical analysis. Furthermore, the anthocyanin content (mg/100 g) in dried herb was determined colorimetrically according to the method described by (Abou-Arab *et al.*, 2011) and adopted by Francis (2000) for *Hibiscus sabdariffa*. Total chlorophyll (SPAD unit) was determined in roselle fresh leaves by using SPAD-502 meter as reported by Markwell *et al.* (1995).

Total carbohydrate percentage in dry sepals was determined according to the method described by Dubois *et al.* (1956), total nitrogen percentage was determined

in dry sepals according to the methods described by **Chapman and Pratt (1978)**, Phosphorus percentage was determined in roselle sepals according to the methods adapted by **Hucker and Catroux (1980)**. Potassium percentage was determined in sepals by using flame photometer according to the method described by **Brown and Lilleland (1946)**.

Statistical analysis:

The obtained data were statistically analyzed and the means were compared using least significant difference (L.S.D) at 5% level as reported by **Gomez and Gomez (1984)**. The means were compared utilizing computer program of Statistix version 9 (**Analytical software, 2008**).

Results and discussions:

Plant growth parameters:

The data given in Table 2 show that branch number/plant and foliage dry weight roselle plant and root dry weight per plant were gradually increased with delaying pinching time in the two consecutive seasons. Control plants (without pinching) gave significantly higher plant height (168.22 and 172.89 cm) compared to pinched plants during the first and second seasons, respectively. The increases in number of branches per plant were about 49.94 and 38.49 % for pinching treatment after 12 weeks from sowing date compared to pinching after 4 weeks from sowing date in 1st and 2nd seasons, respectively. However, the decreases in foliage dry weight per plant were about 14.94 and 14.12 % for pinching treatment after 4 weeks from sowing date compared to pinching after 12 weeks from sowing date in 1st and 2nd seasons, respectively.

Table 2, Effect of pinching date (A), potassium fertilization rate (B) as well as their combinations (A×B) on plant height, number of branches per plant, foliage dry weight per plant and roots dry weight per plant of *Hibiscus sabdariffa* plant during 2019 and 2020 seasons

Treatments	Plant height (cm)		Number of branches/plant		Foliage dry weight/plant (g)		Roots dry weight/plant (g)	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
Pinching date (weeks after sowing date) (A)								
4	168.22	172.66	7.89	8.86	66.33	68.33	27.77	26.80
6	166.94	169.66	8.86	9.25	70.88	72.38	31.18	29.36
8	165.75	168.25	10.14	10.94	72.43	76.29	32.31	31.67
12	161.44	164.22	11.83	12.27	77.98	79.56	34.23	34.58
LSD 5%	1.16	0.75	0.48	0.16	1.00	0.79	0.67	0.76
Potassium fertilization rate (K₂O kg/ feddan) (B)								
Control	160.44	161.50	8.52	8.91	66.78	69.09	28.40	27.32
25	163.36	166.14	9.44	10.16	70.82	73.33	31.51	29.40
50	167.83	171.77	10.16	10.80	73.78	75.79	32.00	31.82

	75	170.72	175.39	10.58	11.44	76.24	78.36	33.57	33.88
	LSD 5%	1.12	0.91	0.33	0.30	0.74	0.60	0.56	0.47
Combination between pinching date and potassium fertilization rate (A×B)									
4 weeks	Control	165.22	161.11	7.22	8.44	61.33	65.43	27.00	25.23
	25	165.89	171.00	7.55	8.77	66.13	66.90	28.03	26.30
	50	169.89	176.11	8.22	8.99	67.80	69.50	27.63	26.70
	75	171.89	182.44	8.55	9.22	70.03	71.50	28.40	28.97
6 weeks	Control	159.22	164.11	7.99	8.22	65.40	67.27	28.50	26.60
	25	165.44	168.77	8.55	9.22	69.93	72.00	30.30	28.47
	50	171.00	173.22	9.44	9.55	72.90	73.77	32.57	31.23
	75	172.11	172.55	9.44	10.00	75.30	76.50	33.33	31.13
8 weeks	Control	160.89	161.66	8.66	9.11	66.77	70.13	29.17	27.33
	25	163.66	163.89	9.89	10.55	70.07	75.47	32.17	29.10
	50	167.22	172.22	10.77	11.66	74.47	78.60	33.13	33.50
	75	171.22	175.22	11.22	12.44	78.63	80.97	34.77	36.73
12 weeks	Control	156.44	159.11	10.22	9.89	73.63	73.53	28.93	30.10
	25	158.44	160.89	11.77	12.11	77.13	78.93	35.53	33.73
	50	163.22	165.55	12.22	12.99	79.97	81.30	34.67	35.83
	75	167.66	171.33	13.11	14.11	81.20	84.47	37.77	38.67
	LSD 5%	2.26	1.74	0.74	0.53	1.63	1.30	1.17	1.11

In addition, increasing potassium fertilization rate from 25 to 75 kg per feddan gradually increased all roselle growth parameters compared to control in both seasons (Table 2). The increases in root dry weight per plant were about 18.20 and 24.01 % for 75 kg potassium fertilization rate compared to control in the first and second seasons, respectively. The highest values in branch number/plant and foliage dry weight of roselle plant and root dry weight per plant obtained when roselle plants pinched after 12 weeks from sowing date combined with highest rate of potassium fertilization (75 kg K₂O/feddan) compared to the other combination treatments under study. In contrast, the tallest plants were achieved when roselle plants pinched after 6 and 4 weeks from sowing date combined with highest rate of potassium fertilization (75 kg K₂O/feddan) compared to the other combination treatments in the first and second seasons, respectively.

Asangi and Vasundhara (2013) showed that the decrease in height of plant appears to be due to slowing down of rate of cell division and drooping in elongation of cell. Also, Ibrahim (2017) found that pinching marigold plants recorded the significant increase in plant height and branch number/plant as well as dry weight of foliage/plant. Moreover, it is well known that K as chemical fertilization could enhance plant development and growth parameters due to the role of potassium as an activator of many enzymes (Helgi and Rolfe, 2005). These results are in accordance with those stated by Mostafa (2019) on *Stevia rebaudiana* plants. Furthermore, as mentioned above, both pinching time treatments and potassium fertilization rates (each alone) increased growth parameters of roselle plant, in turn; they together might maximize their influences leading to taller, more branches and heaviest total dry weight of *Hibiscus sabdariffa* plant.

Yield components:

It is quite clear from the data in Table 3; Figs 1, 2 and 3 that delaying pinching date from 4 to 12 weeks gradually increased number of fruits per plant, dry sepals yield per plant (g) and per feddan (kg). The increases in number of fruits per plant were about 30.70 and 40.45 % for pinching treatment after 12 weeks from sowing date compared with pinching after 4 weeks from sowing date in 1st and 2nd seasons, respectively. In addition, the best treatment to increase number of fruits per plant, dry sepals yield per plant and per feddan were 75 kg K₂O per feddan compared to the lowest rates under study during both seasons. The increases in dry sepals yield per feddan were about 31.96 and 44.29 % for 75 kg potassium fertilization rate compared to control (without potassium fertilization) in the 1st and 2nd seasons, respectively. There was a gradual increase in roselle yield components as potassium fertilization increases. In conclusion, the combination between pinching at 12 weeks from sowing and 75 kg K₂O/ feddan and produced the maximum number of fruits per plant (238.50 and 247.93), dry sepals yield per plant (77.53 and 80.97) and feddan (1085.50 and 1033.50) with significant difference between the other ones under study during first and second seasons, respectively. Also, increasing rate of potassium fertilization under each pinching time treatment gradually increases roselle yield components during the two consecutive seasons.

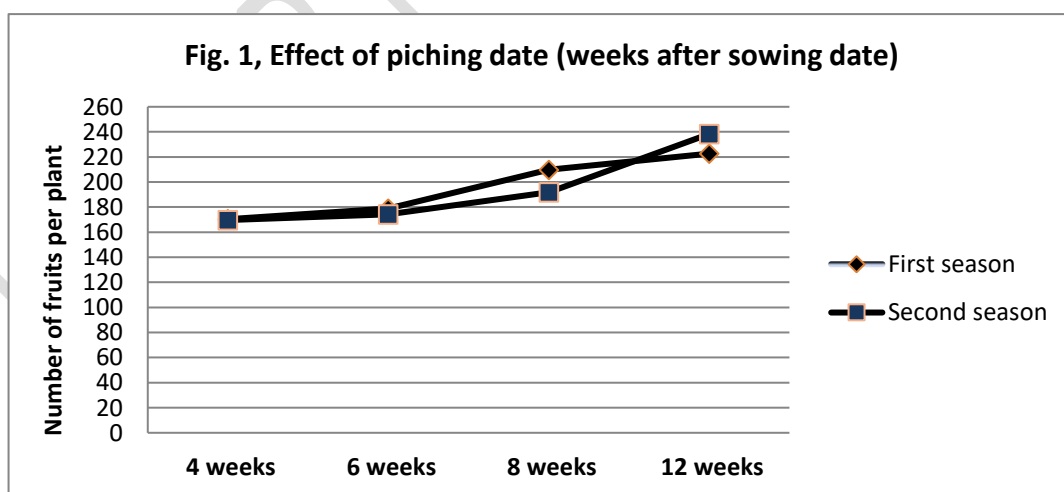
Moreover, pinching causes a significantly increased in fruits number of black cumin compared to un-pinched plants (Hammo, 2008). Kumar *et al.* (2014) reported that stevia plants pinched at 40 days after transplanting recorded significantly higher number of leaves per plant, fresh leaf weight at 1st harvest and about 27.7 % higher total dry biomass of leaves as compared with control. These results also reported by Maurya *et al.* (2013) and Mohammed and Saeid (2020) on okra plant.

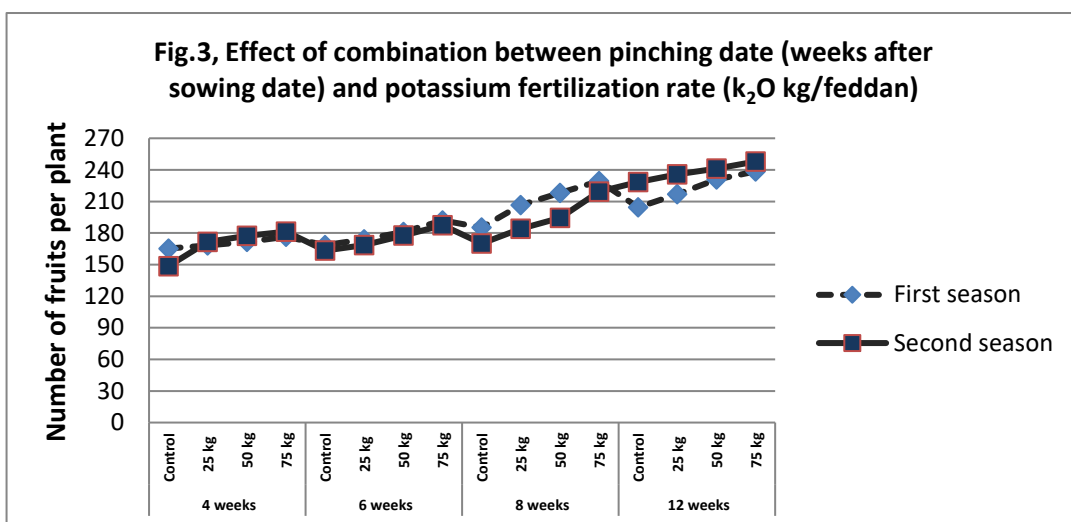
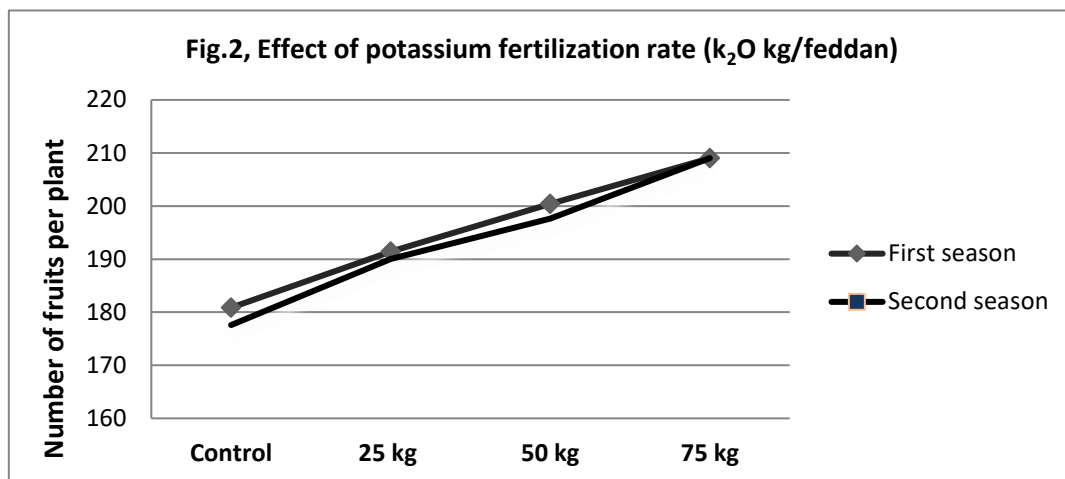
Table 3, Effect of pinching date (A), potassium fertilization rate (B) as well as their combinations (A×B) on sepals yield per plant, sepals yield per feddan, anthocyanin content and total chlorophyll content of *Hibiscus sabdariffa* plant during 2019 and 2020 seasons

Treatments	Sepals yield per plant (g)		Sepals yield per feddan (kg)		Anthocyanin content (mg/100 g as dry weight)		Total chlorophyll content (SPAD)	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
Pinching date (weeks after sowing date) (A)								
4	42.88	42.83	600.37	599.60	13.02	12.78	40.47	40.44
6	48.72	46.08	682.03	645.20	13.48	13.94	41.03	41.23
8	57.48	52.97	804.65	741.50	15.73	14.92	42.32	42.18
12	67.20	72.93	940.80	1020.90	14.82	14.68	42.99	43.38
LSD 5%	1.07	0.69	14.96	9.68	0.52	0.24	0.35	0.62
Potassium fertilization rate (K₂O kg/ feddan) (B)								
Control	46.57	42.99	651.93	601.88	13.53	13.14	40.93	40.73
25	52.33	51.43	732.55	719.95	14.06	14.00	41.47	41.51
50	55.93	58.35	783.07	816.90	14.33	14.29	41.84	42.21
75	61.45	62.03	860.30	868.47	15.13	14.89	42.58	42.78

LSD 5%		0.66	0.48	9.23	6.78	0.25	0.24	0.31	0.30
Combination between pinching date and potassium fertilization rate (A×B)									
4 weeks	Control	39.27	30.77	549.70	430.70	12.37	12.30	39.97	39.83
	25	42.13	44.70	589.90	625.80	12.17	12.67	40.37	40.23
	50	43.83	46.67	613.70	653.30	13.17	12.87	40.57	40.50
	75	46.30	49.17	648.20	688.30	14.37	13.30	40.97	41.20
6 weeks	Control	40.73	35.57	570.30	497.90	12.43	12.33	40.43	40.03
	25	45.30	43.63	634.20	610.90	13.37	13.70	40.77	40.87
	50	51.00	48.97	714.00	685.50	13.83	14.50	41.10	41.60
	75	57.83	56.17	809.70	786.30	14.27	15.23	41.83	42.40
8 weeks	Control	48.53	41.53	679.50	581.50	14.73	13.50	41.33	40.70
	25	57.47	49.23	804.50	689.30	16.30	15.20	42.00	41.77
	50	59.77	59.27	836.70	829.70	15.60	15.10	42.30	43.13
	75	64.13	61.83	897.90	865.70	16.30	15.87	43.63	43.13
12 weeks	Control	57.73	64.10	808.30	897.40	14.60	14.43	41.97	42.37
	25	64.40	68.13	901.60	953.9	14.40	14.43	42.73	43.17
	50	69.13	78.50	967.90	1099.00	14.70	14.70	43.40	43.60
	75	77.53	80.97	1085.50	1033.50	15.57	15.17	43.87	44.37
LSD 5%		1.56	1.08	21.82	15.17	0.68	0.48	0.64	0.81

Likewise, **Khatib (2016)** indicated that potassium fertilizer at various levels increased number of fruit per roselle plant and sepal yield (fresh and dry) compared to control. **Abdelkader and Mostafa (2019)** found that the highest values of pods number/plant, seed yield/plant and /faddan of cluster bean were achieved with 50 kg k₂O per feddan. Similarly, **El-Gamal (2015)** suggested that the best interaction treatment was potassium sulphate and pinching at 10 cm achieved improving *Calendula officinalis* flowers yield with 60% over than the control (average of two seasons).





Chemical constituents:

The data illustrated in Tables 3 and 4 point out that delaying pinching date from 4 to 8 weeks gradually increased anthocyanin content then it was decreased at 12 weeks pinching date. The highest values in total chlorophyll content as well as total carbohydrates, total phosphorus and potassium percentages were produced when roselle plants pinched after 12 weeks from sowing date compared to the other dates under study. However, pinching roselle plants after 12 and 8 weeks from sowing date recorded the highest values of total nitrogen percentage in first and second seasons, respectively. In general, chemical constituents of *Hibiscus sabdariffa* gradually increased as potassium fertilization increased. Furthermore, the highest values in this connection were noticed when roselle plants fertilized with 75 kg k_2O per feddan with significant differences between this rate and the other ones under study, in most cases. Also, all combination treatments between pinching dates and potassium fertilization rates increased anthocyanin content in dry sepals, total chlorophyll (SPAD) in roselle leaf tissues as well as total carbohydrates, N, P and K percentages in dry sepals as compared the control. In addition, the highest values in this concern were obtained from interaction treatment between pinching at 12 weeks from sowing and 75 kg

K₂O/ feddan in both seasons, with significant increase compared to unfertilized roselle and pinched after 4 weeks from sowing date plots.

Furthermore, **El-Sadek (2016)** demonstrated that pinching increased the content of total carbohydrates in *Hibiscus rosa-sinensis* leaves. Also, **Sharaf-Eldien et al. (2017)** stated that the pinching raised N, P and K percentages but it decreased chlorophyll (a+b) content of *Zinnia elegans* plant. In the same time, **Noor El-Deen (2020)** revealed that pinching *Ruellia simplex* after one month from transplanting date increased total chlorophyll content compared to non-pinching treatment and after one and three months from transplanting date.

However, increasing potassium fertilization level increased total chlorophyll content as well as total carbohydrates and K percentages in lavender leaves (**Helaly and Hegazy, 2016**). The application of K at (120 kg/ha) enhanced chlorophyll content, while, the application of K (80 kg/ha) significantly increased wheat grain nitrogen, phosphorus and potassium contents (**Ali et al., 2019**).

Conclusion:

From above obtained results, it is preferable to pinching roselle plants after 12 weeks from sowing date with potassium fertilization at 75 kg K₂O/ feddan to improve the roselle growth, sepals yield, anthocyanin content and total chlorophyll content as well as chemical constituents of *Hibiscus sabdariffa* plant under Sharkia Governorate conditions.

Table 4, Effect of pinching date (A), potassium fertilization rate (B) as well as their combinations (A×B) on total carbohydrates percentage, total nitrogen percentage, total phosphorus percentage and potassium percentage of *Hibiscus sabdariffa* plant during 2019 and 2020 seasons

Treatments	Total carbohydrates (%)		Total nitrogen (%)		Total phosphorus (%)		Potassium (%)	
	1 st	2 nd	1 st	2 nd	1 st	2 nd	1 st	2 nd
Pinching date (weeks after sowing date) (A)								
4	14.84	14.67	2.314	2.307	0.401	0.413	2.448	2.458
6	15.31	15.36	2.371	2.393	0.423	0.434	2.488	2.570
8	15.86	16.29	2.507	2.495	0.453	0.461	2.592	2.652
12	17.05	17.16	2.518	2.470	0.502	0.521	2.710	2.709
LSD 5%	0.35	0.62	0.019	0.009	0.010	0.006	0.017	0.011
Potassium fertilization rate (K₂O kg/ feddan) (B)								
Control	14.83	14.98	2.359	2.431	0.414	0.424	2.497	2.533
25	17.78	15.42	2.408	2.382	0.438	0.450	2.533	2.579
50	15.94	16.28	2.453	2.452	0.454	0.468	2.576	2.618
75	16.52	16.79	2.490	2.490	0.473	0.488	2.632	2.659
LSD 5%	0.31	0.30	0.009	0.007	0.006	0.007	0.008	0.007
Combination between pinching date and potassium fertilization rate (A×B)								

4 weeks	Control	14.17	14.00	2.293	2.250	0.370	0.387	2.407	2.420
	25	14.83	14.30	2.303	2.287	0.403	0.410	2.417	2.427
	50	15.03	15.07	2.317	2.330	0.407	0.423	2.480	2.470
	75	15.33	15.30	2.343	2.360	0.423	0.433	2.490	2.517
6 weeks	Control	14.07	14.53	2.317	2.337	0.407	0.413	2.437	2.467
	25	15.37	14.97	2.363	2.377	0.413	0.423	2.460	2.573
	50	15.57	15.57	2.393	2.410	0.427	0.443	2.500	2.597
	75	16.23	16.27	2.410	2.447	0.447	0.457	2.553	2.643
8 weeks	Control	14.70	15.20	2.403	2.393	0.423	0.427	2.533	2.610
	25	15.73	15.97	2.463	2.440	0.443	0.453	2.567	2.620
	50	15.93	16.70	2.550	2.557	0.463	0.473	2.593	2.670
	75	17.07	17.30	2.610	2.590	0.483	0.490	2.673	2.707
12 weeks	Control	16.37	16.20	2.423	2.383	0.457	0.470	2.610	2.637
	25	17.17	16.43	2.503	2.423	0.493	0.513	2.690	2.697
	50	17.23	17.70	2.550	2.510	0.520	0.530	0.730	2.733
	75	17.43	18.30	2.597	2.563	0.537	0.570	0.810	2.770
LSD 5%		0.50	0.36	0.024	0.015	0.014	0.014	0.022	0.016

REFERENCES

- Abdelkader, M. A. I. and H. Sh. Mostafa (2019).** Response of productivity and chemical constituents of cluster bean (*Cyamopsis tetragonoloba* Taub.) plant to potassium fertilization and humic acid rates. *The Future Journal of Biology*, 2 (1): 29-38.
- Abou-Arab, A. A.; F. M. Abu-Salem and E. A. Abou-Arab (2011).** Physico-chemical properties of natural pigments (anthocyanin) extracted from roselle calyces (*Hibiscus subdariffa*). *J. Am. Sci.* 7:445-456.
- Ali, I.; A. A. Khan; F. Munsif; L. He; A. Khan; S. Ullah; W. Saeed; A. Iqbal; M. Adnan and J. Ligeng (2019).** Optimizing rates and application time of potassium fertilizer for improving growth, grain nutrients content and yield of wheat crop. *Open Agriculture*, 4: 500-508.
- Analytical Software (2008).** Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.
- Asangi, H. and M. Vasundhara (2013).** Effect of pinching and growth regulators on growth, herbage yield, essential oil content and oil yield of patchouli (*Pogostemon patchouli* Pellet.). *J. Hortl. Sci.*, 8(2):214-216.
- Bekele, M. (2018).** Effects of different levels of potassium fertilization on yield, quality and storage life of onion (*Allium cepa* L.) at Jimma, Southwestern Ethiopia. *J. Food Sci. Nutr.*, 1 (2): 32-39.
- Brown, J. D. and O. Lilleland (1946).** Rapid determination of potassium and sodium in plant material and soil extracts by Flame Photometry. *Proc. Amer. Soc. Hort. Sci.* 48: 341-46.
- Cakmak, I. (2005).** The role of potassium in alleviating detrimental effects of abiotic stress in plants. *J. Plant Nutr. Soil Sci.*, 168: 521-530.

- Chapman, D. H. and R. F. Pratt (1978).** Methods of Analysis for Soils, Plants and Waters. Div. Agric. Sci. Univ. of California USA pp16-38.
- Cobley, L. S. (1968).** An introduction to Botany of Tropical Crops. Longman, London, p: 95-98.
- Dubois, M.; Gilles, K. A.; Robers, J. H. and F. Smith (1956).** Colorimetric methods for determination of sugar and related substances. Anal. Chem., 28: 350-356.
- El-Gamal, M.A. Seham (2015).** Influence of pinching and potassium sources on growth and flowers yield of *Calendula officinalis*. Egypt. J. Hort., 42 (1): 639-654.
- El-Sadek, Z. H. (2016).** Effect of pinching and paclobutrazol on *Hibiscus rosa-sinensis*, L. cv. "Yellow" PLANT. Scientific J. Flowers & Ornamental Plants, 3 (4):233-244.
- Francis F. J. (2000).** Anthocyanins and Betalains Composition: Composition and applications. Cereal Foods World, 45: 208-213.
- Gendy, A. G. E.; A. E. E. Gohary; E. A. Omer; S. F. Hendawy; M. S. Hussein; V. Petrova and I. Stancheva (2014).** Effect of nitrogen and potassium fertilizer on herbage and oil yield of chervil plant (*Anthriscus cerefolium* L.). Industrial Crops and Products 69:167–74.
- Gomez, K. A. and A. A. Gomez (1984).** Statistical Procedures for Agricultural Research. John Wiley & Sons Inc., Singapore 680.
- Hafsi, C.; A. Debez and C. Abdelly (2014).** Potassium deficiency in plants: effects and signaling cascades. Acta Physiol. Plant, 36: 1055-1070.
- Hammo, Y. H. (2008).** Effect of high levels of nitrogen and phosphorus fertilizer, pinching, and seed rate on growth and yield components of *Nigella sativa* L.1- Vegetative growth and seed yield. Mesopotamia J. of Agric., 36 (1): 1-12.
- Helaly, A. A. E. and A.A. Hegazy (2016).** Effect of lithovit rate as nano-fertilizer on growth and productivity of *Lavandula officinalis* plant under different potassium fertilization levels. Middle East Journal of Agriculture Research, 5 (4): 899-908.
- Helgi, O. and S. A. Rolfe (2005).** The Physiology of Flowering Plants. 4th ed., Cambridge University Press, Cambridge UK., pp:100-106.
- Hucker, T. W. G. and G. Catroux (1980).** Phosphorus in sewage ridge and animal waste slurries. Proceeding of the EEC Seminar, Haren (Gr); Groningen Netherlands 12, 13 June.

- Ibrahim, R. Fatma (2017).** Impact of pinching on growth and yield of marigold plant under potassium fertilizer combined with some stimulates. *Current Science International*, 6 (4): 955-963.
- Ismail, A.; H. K. I. Emmy and S. M. N. Halimatul (2008).** Roselle (*Hibiscus sabdariffa* L.) seeds nutritional composition, protein quality and health benefits. *Food Global Science Books*, 2 (1): 1-16.
- Khatab, A. Kh. (2016).** Response of roselle plants (*Hibiscus sabdariffa* L.) to pressed olive cake compost types and potassium fertilization rates on newly reclaimed soils at Siwa Oasis, Egypt. *J. Soil Sci. and Agric. Eng., Mansoura Univ.*, 7 (5): 365 – 373.
- Kumar, R.; S. Sharma and M. Sharma (2014).** Growth and yield of natural-sweetener plant stevia as affected by pinching. *Ind. J. Plant Physiol.*, 19 (2):119–126.
- Mahadevan, N. and K. P. Shivali (2009).** *Hibiscus sabdariffa* Linn.: An overview. *Natural Product Radiance*, 8: 77–83.
- Makinde, A.I.; M.O. Oluwafemi and M.O. Raji (2016).** Effects of pinching height on the growth and calyx yield of roselle (*Hibiscus sabdariffa* L.). *Acta SA Tech.*, 7(1): 6-13.
- Marie, A. I.; A. Ihsan and S. H. Salih (2007).** Effect of sowing date, topping and some growth regulators on growth, pod and seeds yield of okra (*Abelmoschus esculentus* L.). *African Crop Science Conference Proceedings*, 8: 473-478.
- Markwell, J.; J. C. Osterman and J. L. Mitchell (1995).** Calibration of the Minolta SPAD-502 leaf chlorophyll meter. *Photosynthesis Res.*, 46: 467-472.
- Marschner, H. (1995).** Mineral nutrition of higher plants, 2nd Edition. London: Academic Press.
- Maurya, R. P.; J. A. Bailey and J. St. A. Chandler (2013).** Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (*Abelmoschus esculentus* (L.) Moench). *American Journal of Agriculture and Forestry*, 1 (4): 48-54.
- Mohammed, G. H. and A. I. Saeid (2020).** Evaluation of apical pinching, humic acid and plastic mulch on different characters of okra (*Abelmoschus esculentus* L.). *Pak. J. Bot.*, 52 (1): 139-146.
- Mostafa, H. Sh. (2019).** Impact of NPK fertilization and lithovit rates on growth, yield components and chemical constituents of *Stevia rebaudiana* Bert. plant. *Middle East Journal of Applied Sciences*, 9 (2): 412- 420.

- Noor El-Deen, T. M. (2020).** Production of stunted pot plants from *Ruellia simplex*. Middle East Journal of Agriculture Research, 9 (2): 308-320.
- Pal, P.; R. S. Adhikari and J. S. Negi (2016).** Effect of nitrogen, phosphorus and potassium on growth and green herb yield of *Thymus serpyllum*. Int. J. Curr. Microbiol. App. Sci., 5 (1): 406-410.
- Sharaf-Eldien, M. N.; S. Z. El-Bably and M. R. Magouz (2017).** Effect of pinching and spraying of paclobutrazol on vegetative growth, flowering and chemical composition of *Zinnia elegans*, Jacq. J. Plant Production, Mansoura Univ., 8 (5):587-592.
- Singh, R. K.; A. K. Sureja and D. Singh (2006).** Amta and amti (*Hibiscus sabdariffa* L.) cultural and agricultural dynamics of agrobiodiversity conservation. Indian Journal of Traditional Knowledge 5(1), 151-157.
- Zrig, A.; J. F. S. Ferreira; F. Hamouda, T.b Tounekti, S. Selim, S. Al Jaouni, H. Khemira and H. Abdelgawad (2019).** The impact of foliar fertilizers on growth and biochemical responses of *Thymus vulgaris* to salinity stress. Arid Land Research and Management, 10: 1-24.