

Maximizing growth and antioxidants of carrot plant (*Dacus carota* L.) by foliar application of hornwort extract, Phenylalanine and Nano-Potassium

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Abstract

Two field trials were conducted in Babylon governorate, Tufael town which is located in Al-Kifl district in a mixed sandy soil for the growing seasons 2021-2022 and 2022-2023 to assess impact of hornwort extract, phenylalanine amino acid and nano-potassium and its interactions on growth and antioxidants accumulation of carrots plant. The treatments were implemented within Randomized Complete Block Design (R.C.B.D) with three factors and three replications. The trial comprised three factors, the first is spraying hornwort extract with three concentrations 0, 4 and 8 ml. L⁻¹, the second factor included the spraying amino acid Phenylalanine with three concentrations 0, 75 and 150 mg.L⁻¹ and the third factor included the spraying nano-potassium fertilizer with three concentrations 0, 1 and 2 g.L⁻¹. The averages were compared according to the least significant difference (L.S.D) test at a probability level of 0.05. The results showed that the triple-interaction (A3B3C3) between hornwort extract (8ml.L⁻¹), phenylalanine (150mg.L⁻¹) and nano-potassium (2g.L⁻¹) was superior to all treatments in achieving the highest values in leaf area (112.30, 116.10 cm²), leaves fresh weight (61.25, 66.56 g), total chlorophyll content of leaves (290.09, 305.20 mg.100 f.w), beta-carotene (10.05, 10.19 mg.100 f.w) and ascorbic acid (7.80, 8.20 mg.100 ml f.w) for two seasons respectively. The favorable formulation that carrot strongly respond with is A3B3C3 treatment.

Keywords: hornwort, Phenylalanine (phe), nano-potassium (K), carrots (*Daucus carota* L).

Introduction

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Carrots (*Daucus carota* L.) is essential crop vegetable which related to Apeaceae family. It is biennial crop developing root and leaves until the end of its growing season (24). people used to include carrots consumption in their diet because it is rich source of anti-oxidant (33). Awareness of healthy food has been increased in recent days due to rise many health issues of cancer, high blood pressure, diabetes and heart disease as a result of following a wrong diet for several years (19). Therefore, this motivates people to involves a rich vegetable of antioxidant in their daily diet as therapeutic nutrition. Orange carrot like other many colorful vegetable is rich of antioxidant like beta carotene and vitamin C that play an important role in body health maintenance (29, 13), therefore carrot crop is ranked 10th in terms of nutritional value (3). Thus, planting of carrots has become within researchers' attention to meet people's demand globally. Foliar spray of hornwort extract has been frequently used in recent years to promote carrot quality because it is rich of NPK and Ca elements, vitamin C, plant hormones and amino acids (4, 5). Spraying hornwort (20ml.L⁻¹) increased growth and NPK of cucumber's leaves (4), as increased N enhances biosynthesis of ascorbic acid (30) and increasing P element lead to promote carotenoids in the plant because it enhances biosynthesis of all carotenoids (28). Phenylalanine is essential main amino acid that play a key role in stimulating growth and development because it contributes in biosynthesis plant hormones specially gibberellin (32). As spraying plants with amino acid increased ascorbic acid and

carotenoids (10). Nano fertilizers are different from traditional fertilizers due to their small size and increased surface area which leads to increase absorption surface and thus ability to improve nutrients efficiency via certain mechanisms like slow release nutrients for the target plant organ which resulting in promoting photosynthesis and consequently increased nutrient accumulation in the plant (27, 31). Potassium fertilizer is most demand root crop because it activate 60 enzyme of bio-process (20). The aim of this study is to study impact of hornwort extract, amino acid phenylalanine and nano-potassium and it's interaction on growth and antioxidants accumulation of carrots plant.

Materials and Methods

The research investigation was conducted for the winter seasons 2021-2022 and 2022-2023 in Babylon governorate, Tufael town which is about 15 km of Hilla city at longitude 44. 39 degrees East and latitude 32.30 North in a mixed sandy soil to evaluate role of foliar application of hornwort extract, Phenylalanine and nano-potassium in maximizing growth and antioxidant of carrot plant. Field soil analysis was done before planting as chemical and physical properties for both seasons were shown in (Table 1).

The field land of two trials was plowing twice perpendicularly, then it was flatten and leveled well and divided into three blocks with 27 plot each. Plot size was 1X1m² with 50cm between plots and 1m between blocks (17). Both experiments conducted on 21/09/2021 and 21/09/2022 for both growing seasons . Carrots seed of Nantes cultivar were produced by MONARCH SEED Company.



Seeds was sowed by hand in rows with distance of 20 cm between rows. Weeds were removed manually specially during first stages of plant growth for several times and irrigation (conventional system) was carried out whenever needed. Plants were thinned 1 month after planting to the space of approximately 10 cm apart within each row (9, 11, 14).

The experiment included three factors. The first factor is spraying hornwort extract with three concentrations 0, 4 and 8 ml. L⁻¹ which symbolized (A1, A2, A3). Hornwort extract (Table 2) was prepared by collecting hornwort plants from the rivers. Then, they were washed with distilled water in the laboratory several times to get rid of the mud and suspended stuff. Then, 250 g of hornwort was taken and chopped into small pieces and placed in an electric mixer with addition 250 ml of distilled water and mixed well for 10 minutes. after that, a piece of soft cloth was used to separate the extract from the plant residue to obtain an a pure extract of 50% of

hornwort extract (6). The second factor was spraying amino acid Phenylalanine with 3 concentrations of 0, 75 and 150 mg.L⁻¹ which symbolized (B1, B2, B3) and third factor was spraying nano-potassium fertilizer with 3 concentrations 0, 1 and 2 g.L⁻¹ which symbolized (C1, C2, C3). Comparison treatments (A1, B1 and C1) included spraying with distilled water only. The period of spray between factors was seven days. Carrots plant were sprayed three times, the first spray was applied 10 days after thinning stage , the second spray was 21 days after the first spray and the third spray was 14 days after the second spray.

Samples of 10 plants were taken from each plot to record vegetative parameters (leaf area, leaves fresh weight and total chlorophyll of leaves (16) and calculating root content of beta-carotene of (26) and ascorbic acid (1). Collected data were analyzed using analyses of variance and averages were compared according to L.S.D at a probability level of 0.05 (8).

Table 1. Physical and chemical properties of pre-sowing soil

Character	Values	
	2021-2022	2022-2023
pH	7.98	7.6
EC (ds.m ⁻¹)	3.1	2.7
N (mg. kg ⁻¹)	79.1	82.1
P (mg. kg ⁻¹)	10.6	8.6
K (mg. kg ⁻¹)	110	188
Ca (Meq L ⁻¹)	140	130
Mg (Meq L ⁻¹)	250	450
Na (Meq L ⁻¹)	29.8	22.6
Cl ⁻ (Meq L ⁻¹)	3700	1480
So ₄ (Meq L ⁻¹)	35	4.36
HCO ₃ (Meq L ⁻¹)	1.2	0.8
O.M (%)	1.1	1.37

Gypsum (%)	4	3
Sand g.kg ⁻¹	768	654
Silt g.kg ⁻¹	100	187
Clay g.kg ⁻¹	132	159
Texture	Mixed sandy	Mixed sandy

Table 2. Chemical composition of hornwort extract

	Character	Value
%	N	11.84
	P	4.32
	K	15.62
	Ca	3.731
Ppm	IAA	124.6
	GA3	330.2
	Cytokinins	181
	Vitamin	C445.1
	Glutamic acid	41.129
	Serine	1720.63
	Glycine	211.26
	Threonine	3706.46
	Valine	449.43
	Tryptophan	60.55
	Phenylalanine	261.89

Results and Discussion

Vegetative growth parameters

From (Tables 3, 4, 5), it is clear that there is a significant influence of individual factors in leaf area, leaves fresh weight and total chlorophyll of leaves. Plant sprayed with hornwort extract (8.ml.L⁻¹) produced the highest values of leaf area (100.37, 103.47cm), fresh weight of leaves (56.38, 58.85g) and total chlorophyll of leaves (255.32, 268.91 mg.100g⁻¹ F. W) for two seasons respectively compared to lowest value in control treatment (A1). Foliar spray of phenylalanine (150mg.L⁻¹) achieved the

highest means of leaf area, leaves fresh and total chlorophyll of leaves for two seasons compared to lowest means that were found in comparison treatment (B1) for two reasons. Spraying nano-K (2g.L⁻¹) was superior in leaf area (99.95, 102.63 cm), leaves fresh weight (56.03, 58.33 g) and total chlorophyll of leaves (253.98, 267.56 mg.100g⁻¹ F. W) while the lowest means were found in control treatment (C1).

Also, result of same tables showed that there was a significant impact of bi-interaction in leaf area, leaves fresh weight and total chlorophyll of leaves. Plant that treated with



hornwort extract (8ml.L^{-1}) and phenylalanine (150mg.L^{-1}) produced the highest leaf area ($106.28, 109.62\text{ cm}$), leaves fresh weight ($59.30, 62.61\text{g}$) and total chlorophyll of leaves ($270.12, 286.16\text{ mg.100g}^{-1}\text{ F. W}$) for both seasons respectively compared to the comparison treatment (A1B1) that displayed the least means. Bi-interaction between hornwort extract (8ml.L^{-1}) and nano-potassium (2g.L^{-1}) display the highest leaf area ($107.90, 110.13\text{cm}$), leaves fresh weight ($59.58, 63.22\text{g}$) and total chlorophyll of leaves ($272.74, 288.51\text{ mg.100g}^{-1}\text{ F. W}$). Plants were sprayed with B3C3 treatment achieved the highest averages of leaf area ($105.93, 109.17\text{ cm}$), leaves fresh weight ($58.95, 62.15\text{ g}$) and total chlorophyll of leaves ($269.09, 285.15\text{ mg.100g}^{-1}\text{ F. W}$). Regarding the tri-interaction. The most impact was evident in (A3B3C3) treatment that achieved the highest means of leaf area ($112.30, 116.10\text{ cm}$), leaves fresh weight ($61.25, 66.56\text{ g}$) and total chlorophyll of leaves ($290.09, 305.20\text{ mg.100g}^{-1}\text{ F. W}$) for two seasons respectively compared to lowest means $74.70, 77.40\text{ (cm)}$, $42.20, 40.10\text{ (g)}$ and $180.36, 186.05\text{ (mg.100g fresh weight)}$ that were found in control treatment (A1B1C1) respectively.

Antioxidant parameters in root of carrots.

The results of (Tables 6, 7) indicated that there is a significant effect in ascorbic acid and beta-carotene when treating plants with hornwort extract (8ml.L^{-1}) as the results reached ($6.84, 7.25\text{ mg.100ml}$) and ($8.61, 8.91\text{ mg.100g}^{-1}\text{ F.W}$) for both seasons respectively compared to the lowest values in control treatment (A1). Plants that were sprayed with 150mg.L^{-1} treatment displayed a

significant increase in ascorbic acid ($6.74, 7.16\text{ mg.100 ml}$) and beta-carotene ($8.48, 8.76\text{ mg.100g}^{-1}\text{ F.W}$) for both seasons compared to the comparison treatment (B1) that displayed the lowest values. plants were treated with nano-potassium (2g.L^{-1}) displayed a significant increase in ascorbic acid ($6.80, 7.20\text{ mg.100 ml}$) and beta-carotene ($8.56, 8.85\text{ mg.100g}^{-1}\text{ F.W}$) while lowest values were found in comparison treatment (C1). The results of same tables, showed a significant impact for bi-interact between hornwort extract and Phenylalanine. Plants sprayed with (A3B3) treatment showed the highest values of ascorbic acid ($7.28, 7.70\text{ mg.100 ml}$) and beta-carotene ($9.21, 9.47\text{ mg.100g}^{-1}\text{ F.W}$) while lowest averages were found in comparison treatment (A1B1) for both seasons. Plant that sprayed with (A3C3) treatment demonstrated the highest ascorbic acid ($7.34, 7.73\text{ mg.100 ml}$) and beta-carotene ($9.30, 9.57\text{ mg.100g}^{-1}\text{ F.W}$) while lowest averages were found in control treatment (A1C1) for both seasons. Interaction between (B3C3) achieved the highest ascorbic acid ($7.25, 7.67\text{ mg.100 ml}$) and beta-carotene ($9.13, 9.43\text{ mg.100g}^{-1}\text{ F.W}$) for both seasons compared to the control treatment (B1C1) that produced the lowest values. Regarding the tri- interaction, results showed that the most significant impact in ascorbic acid ($7.80, 8.20\text{ mg.100 ml}$) and beta-carotene ($10.05, 10.19\text{ mg.100g}^{-1}\text{ F.W}$) was observed in (A3B3C3) treatment for both seasons compared to the lowest values of ascorbic acid $5.05, 5.40\text{ (mg.100 ml)}$ and beta-carotene $6.84, 7.00\text{ (mg.100 F.W)}$ that were observed in comparison treatment.



Table 3. Effects of hornwort, Phenylalanine (phe) and nano-potassium (K) on leaf area (cm) of carrots plant for both seasons

Treatments		Season 2021-2022				Season 2022-2023			
		Nano-K (g.L ⁻¹)			Hornwort and Phe	Nano-K (g.L ⁻¹)			Hornwort and Phe
Hornwort ml.L ⁻¹	Phe mg.L ⁻¹	0.0	1.0	2.0		0.0	1.0	2.0	
0.0	0.0	74.70	77.90	79.55	77.38	77.40	80.60	83.30	80.43
	75	77.40	84.40	90.54	84.11	78.25	89.20	94.00	87.15
	150	79.00	89.48	94.80	87.76	82.00	92.13	98.30	90.81
4.0	0.0	78.40	86.56	92.75	85.90	81.00	90.90	95.50	89.13
	75	84.90	104.80	107.49	99.06	90.00	106.50	109.08	101.86
	150	90.20	105.90	110.70	102.27	93.04	107.60	113.11	104.58
8.0	0.0	80.30	93.15	99.60	91.02	85.05	97.10	100.15	94.10
	75	91.20	108.40	111.80	103.80	94.90	111.09	114.15	106.71
	150	95.30	111.25	112.30	106.28	99.06	113.70	116.10	109.62
L.S.D 0.05		1.922			1.110	0.221			0.128
Nano-K (g.L ⁻¹) Mean		83.49	95.76	99.95		86.74	98.75	102.63	
L.S.D 0.05		0.641				0.074			
					Hornwort ml.L ⁻¹ mean				Hornwort ml.L ⁻¹ mean
Hornwort and Nano-K	0.0	77.03	83.93	88.30	83.09	79.21	87.31	91.86	86.13
	4.0	84.50	99.09	103.65	95.74	88.01	101.66	105.89	98.52
	8.0	88.93	104.27	107.90	100.37	93.00	107.29	110.13	103.47
L.S.D 0.05		1.110			0.641	0.128			0.074
					Phe ml.L ⁻¹ mean				Phe ml.L ⁻¹ mean
Phe and Nano-K	0.0	77.80	85.87	90.63	84.77	81.15	89.53	92.98	87.88
	75	84.50	99.20	103.28	95.66	87.71	102.26	105.74	98.57
	150	88.17	102.21	105.93	98.77	91.36	104.47	109.17	101.67
L.S.D 0.05		1.110			0.641	0.128			0.074



Table 4. Effects of hornwort, Phenylalanine (phe) and nano-potassium (K) on leaves fresh weight (g) of carrots plant for both seasons

Treatments		Season 2021-2022				Season 2022-2023			
		Nano-K (g.L ⁻¹)			Hornwort and Phe	Nano-K (g.L ⁻¹)			Hornwort and Phe
Hornwort mL.L ⁻¹	Phe mg.L ⁻¹	0.0	1.0	2.0		0.0	1.0	2.0	
0.0	0.0	42.20	44.00	45.10	43.76	40.10	42.20	44.70	42.33
	75	43.20	48.00	52.10	47.76	41.50	50.20	53.10	48.26
	150	44.50	51.00	55.00	50.16	44.05	52.05	55.10	50.40
4.0	0.0	44.35	49.05	53.00	48.80	43.06	51.00	53.80	49.28
	75	48.60	58.90	59.80	55.76	50.30	60.80	63.80	58.30
	150	51.75	59.15	60.60	57.16	52.50	63.00	64.80	60.10
8.0	0.0	46.00	53.55	56.50	52.01	47.20	54.09	57.00	52.76
	75	52.50	60.00	61.00	57.83	53.50	63.95	66.12	61.19
	150	55.90	60.75	61.25	59.30	56.14	65.13	66.56	62.61
L.S.D 0.05		0.022			0.012	0.185			0.107
Nano-K (g.L ⁻¹) Mean		47.66	53.82	56.03		47.59	55.82	58.33	
L.S.D 0.05		0.007				0.061			
					Hornwort mL.L ⁻¹ mean				Hornwort mL.L ⁻¹ mean
Hornwort and Nano-K	0.0	43.30	47.66	50.73	47.23	41.88	48.15	50.96	47.00
	4.0	48.23	55.70	57.80	53.91	48.62	58.26	60.80	55.89
	8.0	51.46	58.10	59.58	56.38	52.28	61.05	63.22	58.85
L.S.D 0.05		0.012			0.007	0.107			0.061
					Phe mL.L ⁻¹ mean				Phe mL.L ⁻¹ mean
Phe and Nano-K	0.0	44.18	48.86	51.53	48.19	43.45	49.09	51.83	48.12
	75	48.10	55.63	57.63	53.78	48.43	58.31	61.00	55.91
	150	50.71	56.96	58.95	55.54	50.89	60.06	62.15	57.70
L.S.D 0.05		0.012			0.007	0.107			0.061



Table 5. Effects of hornwort, Phenylalanine (phe) and nano-potassium (K) on total chlorophyll (mg.100g⁻¹ fresh weight) of carrot plant for both seasons

Treatments		Season 2021-2022				Season 2022-2023			
		Nano-K (g.L ⁻¹)			Hornwort and Phe	Nano-K (g.L ⁻¹)			Hornwort and Phe
Hornwort ml.L ⁻¹	Phe mg.L ⁻¹	0.0	1.0	2.0		0.0	1.0	2.0	
0.0	0.0	180.36	190.05	210.06	193.49	186.05	197.09	210.11	197.75
	75	186.04	225.00	230.10	213.71	194.16	227.15	242.27	221.19
	150	195.02	228.05	237.06	220.04	213.20	238.40	252.12	234.57
4.0	0.0	191.22	229.06	235.07	218.45	200.32	235.06	247.25	227.54
	75	227.09	254.03	275.19	252.11	230.17	275.50	292.60	266.09
	150	229.05	268.08	280.12	259.08	240.45	287.31	298.13	275.30
8.0	0.0	215.13	236.08	240.06	230.42	212.15	250.32	258.16	240.21
	75	231.07	277.13	288.07	265.42	245.32	293.61	302.18	280.37
	150	238.13	282.14	290.09	270.12	254.14	299.15	305.20	286.16
L.S.D 0.05		1.909			1.102	2.829			1.633
Nano-K (g.L ⁻¹) Mean		210.34	243.29	253.98		219.55	255.95	267.56	
L.S.D 0.05		0.636				0.943			
					Hornwort ml.L ⁻¹ mean				Hornwort ml.L ⁻¹ mean
Hornwort and Nano-K	0.0	187.14	214.37	225.74	209.08	197.80	220.88	234.83	217.84
	4.0	215.79	250.39	263.46	243.21	223.65	265.96	279.33	256.31
	8.0	228.11	265.12	272.74	255.32	237.20	281.03	288.51	268.91
L.S.D 0.05		1.102			0.636	1.633			0.943
					Phe ml.L ⁻¹ mean				Phe ml.L ⁻¹ mean
Phe and Nano-K	0.0	195.57	218.40	228.40	214.12	199.51	227.49	238.51	221.83
	75	214.73	252.05	264.46	243.75	223.22	265.42	279.02	255.88
	150	220.73	259.42	269.09	249.75	235.93	274.95	285.15	265.34
L.S.D 0.05		1.102			0.636	1.633			0.943



Table 6. Effects of hornwort, Phenylalanine (phe) and nano-potassium (K) on total Ascorbic acid (mg.100 ml) of carrots plant for both seasons

Treatments		Season 2021-2022				Season 2022-2023			
		Nano-K (g.L ⁻¹)			Hornwort and Phe	Nano-K (g.L ⁻¹)			Hornwort and Phe
Hornwort ml.L ⁻¹	Phe mg.L ⁻¹	0.0	1.0	2.0		0.0	1.0	2.0	
0.0	0.0	5.05	5.27	5.50	5.27	5.40	5.63	5.85	5.62
	75	5.23	5.84	6.14	5.73	5.60	6.22	6.50	6.10
	150	5.47	6.04	6.36	5.95	5.82	6.42	6.76	6.33
4.0	0.0	5.30	5.95	6.20	5.81	5.67	6.32	6.58	6.19
	75	5.89	6.93	7.43	6.75	6.25	7.70	7.83	7.26
	150	6.09	7.30	7.60	6.99	6.55	7.75	8.07	7.45
8.0	0.0	5.54	6.27	6.48	6.09	5.92	6.68	6.88	6.49
	75	6.19	7.51	7.75	7.15	6.60	7.95	8.13	7.56
	150	6.40	7.66	7.80	7.28	6.80	8.10	8.20	7.70
L.S.D 0.05		0.075			0.043	0.059			0.034
Nano-K (g.L ⁻¹) Mean		5.68	6.53	6.80		6.06	6.97	7.20	
L.S.D 0.05		0.025				0.019			
					Hornwort ml.L ⁻¹ mean				Hornwort ml.L ⁻¹ mean
Hornwort and Nano-K	0.0	5.25	5.71	6.00	5.65	5.60	6.09	6.37	6.02
	4.0	5.76	6.72	7.07	6.52	6.15	7.25	7.49	6.96
	8.0	6.04	7.14	7.34	6.84	6.44	7.57	7.73	7.25
L.S.D 0.05		0.043			0.025	0.034			0.019
					Phe ml.L ⁻¹ mean				Phe ml.L ⁻¹ mean
Phe and Nano-K	0.0	5.29	5.83	6.06	5.72	5.66	6.21	6.43	6.10
	75	5.77	6.76	7.10	6.54	6.15	7.29	7.48	6.97
	150	5.98	7.00	7.25	6.74	6.39	7.42	7.67	7.16
L.S.D 0.05		0.043			0.025	0.034			0.019



Table 7. Effects of hornwort, Phenylalanine (phe) and nano-potassium (K) on total Beta-carotene (mg.100 g⁻¹ fresh weight) of carrots plant for both seasons

Treatments		Season 2021-2022				Season 2022-2023			
		Nano-K (g.L ⁻¹)			Hornwort and Phe	Nano-K (g.L ⁻¹)			Hornwort and Phe
Hornwort ml.L ⁻¹	Phe mg.L ⁻¹	0.0	1.0	2.0		0.0	1.0	2.0	
0.0	0.0	6.84	7.00	7.15	6.99	7.00	7.17	7.34	7.17
	75	6.97	7.45	7.65	7.35	7.18	7.58	7.80	7.52
	150	7.10	7.60	7.90	7.53	7.32	7.75	8.20	7.75
4.0	0.0	7.06	7.55	7.79	7.46	7.20	7.65	8.00	7.61
	75	7.50	8.56	9.20	8.42	7.65	9.10	9.70	8.81
	150	7.63	9.00	9.45	8.69	7.76	9.50	9.90	9.05
8.0	0.0	7.20	7.84	8.06	7.70	7.38	8.26	8.50	8.04
	75	7.70	9.25	9.80	8.91	7.90	9.76	10.03	9.23
	150	8.00	9.60	10.05	9.21	8.25	9.97	10.19	9.47
L.S.D 0.05		0.027			0.015	0.037			0.021
Nano-K (g.L ⁻¹) Mean		7.33	8.20	8.56		7.51	8.52	8.85	
L.S.D 0.05		0.009				0.012			
					Hornwort ml.L ⁻¹ mean				Hornwort ml.L ⁻¹ mean
Hornwort and Nano-K	0.0	6.97	7.35	7.56	7.29	7.16	7.50	7.78	7.48
	4.0	7.39	8.37	8.81	8.19	7.53	8.75	9.20	8.49
	8.0	7.63	8.89	9.30	8.61	7.84	9.33	9.57	8.91
L.S.D 0.05		0.015			0.009	0.021			0.012
					Phe ml.L ⁻¹ mean				Phe ml.L ⁻¹ mean
Phe and Nano-K	0.0	7.03	7.46	7.66	7.38	7.19	7.69	7.94	7.61
	75	7.39	8.42	8.88	8.23	7.57	8.81	9.17	8.52
	150	7.57	8.73	9.13	8.48	7.77	9.07	9.43	8.76
L.S.D 0.05		0.015			0.009	0.021			0.012



Foliar spray of hornwort extract on efficiently increased growth parameters. This a significant increase may be due to extract content of hornwort macro elements such as nitrogen, phosphorus, and potassium (Table 2). Nitrogen is essential elements for plant growth, as it is considered one of the main components of chlorophyll that determine and activate photosynthesis (15, 22), nitrogen also maintains leaf surface and increases its durability and consequently enhance rate and duration of photosynthesis and eventually increase plant growth (2, 34). Phosphorus is important to build nucleic, amino acids and coenzyme that involved in respiration and photosynthesis process which lead to accumulation of organic compounds such as proteins, carbohydrates, vitamins and other organic product and eventually promoting biomass and dry matter (2).

Potassium plays a key role as an activator and regulator of proteins biosynthesis, sugars transport, metabolism of nitrogen and carbon (21,25) and thus enhance plant cell growth (18). The amino acid Phenylalanine plays an essential role in enhancing plant growth because its role as suitable alternative for essential nitrogen to build enzymes and proteins that enhance plant growth (7).

Table (6, 7) indicated that foliar application of hornwort, phenylalanine and nano-K had a significant effect in antioxidants such as ascorbic acid and beta-carotene. This could be related to sufficient amount of P and N elements in the root as resulted from foliar spray of hornwort extract (Table2). As increasing P in the root leads to elevate beta-

carotene concentration in the roots because P involved in all intermediate of beta-carotene biosynthesis (12) and increased N enhance biosynthesis of ascorbic acid (30). Also, spraying plants with amino acid has a main role in stimulating plant to absorb NPK due to increase osmotic pressure in plant cells and thus increase absorption of water and nutrients from soil (10). Elevation of N and P in root reinforce concentration of ascorbic acid (30) and beta-carotene in the roots (12).

Furthermore, foliar spray of nano-K had increase antioxidants like carotene in the root and this may be due to role of potassium in activating photosynthesis which forms (Isoprenoids) through a series of reactions. Isoprenoids are Isoprene which some of it unite to form carotene (23).

Conclusion

Two seasons of field experiments authenticate that foliar application of hornwort extract, Phenylalanine and Nano-Potassium had a prominent role in promoting all studied parameters.

Conflict of interest

The authors declare no conflict of interest.

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