Egyptian J. Desert Res., **73**, No. 1, 65-84 (2023)

EFFECT OF SOME ORGANIC TREATMENTS ON THE TOLERANCE OF HIGH TEMPERATURE *CABOTTA LETTUCE* PLANTS UNDER THE HYDROPONICS CULTIVATION SYSTEM

Salama, Yasser A.M.
Plant Adaptation Unit, Department of Genetic Resources, Desert Research Center, Cairo, Egypt
E-mail: yasser.hakim.salama@gmail.com

This study examined the effects of foliar spray of amino acids and thiamin on the yield and quality of iceberg lettuce (*Lactuca sativa*) in the summers of 2020 and 2021 under the hydroponics cultivation method. Aviram and Sara, two hybrids, were raised. Five weeks of once-weekly applications of Aminototal (20% free amino acids) and thiamin at concentrations of 1, 2, and 3 cm^3/L and 0.06, 0.08, and 0.1 g/L, respectively, were conducted. All foliar spray treatments enhanced plant growth when compared to the control. The N, P, K, Ca, and Mg mineral contents benefited from the given treatments. The Aviram hybrid marketable and total yield were most strongly influenced by the foliar spray treatment with the highest amino acid concentration. Contrarily, the control treatment generated the smallest total and marketable yield of lettuce heads (without amino acids and thiamin).

Keywords: lettuce, amino acids, thiamin, hydroponic

INTRODUCTION

With or without mechanical root support, hydroponics is a method of growing plants in which the roots are immersed in a nutritional solution. It is also known as "controlled environment agriculture," or CEA, because growing plants hydroponically requires controlling several environmental factors, including water temperature, light intensity and duration, humidity, solution pH, and mineral fertilizers. Hydroponics provides advantages over soil-based systems due to the more effective use of fertilizers and water, superior control of the growth environment, and insect control (Thakulla et al., 2021).

In many places of the world, lettuce (*Lactuca sativa* L.) is a common crop because of its flavor and nutritional advantages. Lettuce is rich in floats, vitamins A, K, and C (Romani et al., 2002). In addition to being high in vitamins and minerals like iron, calcium, and magnesium, lettuce is typically consumed raw. The cool-season vegetable crop lettuce, on the other hand, bolts in hot temperatures. It was found that exposing lettuce to high temperatures results in the beginning of inflorescences (bolting), which decreases marketability (Waycott, 1995 and Simonne et al., 2002). The iceberg lettuce head formation process is significantly influenced by the growth environment, and this in turn can have an impact on the size and quality of the finished head. Heavy heads are caused by low temperatures around and during heading, but high temperatures hasten maturation (Wurr et al., 1996; Thompson et al., 1998 and Choi and Lee, 2004). Reduced head weight or bolting reduces the marketability of the lettuce, which affects the grower's income. Many academics are interested in this issue because it could help them boost the productivity and quality of iceberg lettuce while it is under heat stress. Although high temperatures lengthened lettuce stems (Rader and Karlsson, 2006 and Fukuda et al., 2012). Cultivar differences also play a role (Zhao and Carey, 2009). Shade can reduce heat stress, according to other research, but the data are conflicting (Abdel-Mawgoud, 1995). Yet, investigations on how certain interventions, including the use of amino acids, affect lettuce productivity and quality under standard production circumstances (Khan et al., 2019). The goal of this study is to ascertain whether providing thiamin or amino acids to lettuce plants grown in hydroponic farms under greenhouses can mitigate the negative effects of heat stress on production and quality throughout the summer in Egypt.

MATERIALS AND METHODS

The experiment investigated the individual effects of amino acids and B complex on mitigating heat stress on lettuce plants produced using the Nutrient Film Technique (NFT) system at a private farm (Elzeini farm), [Latitude 30.2082610, 30.7457860], Monsha'et El-Kanater, Giza governorate. In June 2020 and 2021, the experiment was carried out. Average of relative humidity, temperature and wind Speed in 2020 and 2021 seasons are shown in Table (1).

1. Growth Conditions and Nutrient Solution

Two hybrid iceberg lettuce seedlings named Sara and Aviram were moved to a closed-loop NFT hydroponic system in June 2020 and 2021, respectively. The plastic cups' perforations were left open, allowing the plant roots to crawl out. The used plastic cup was 11 cm in length and 9 cm in diameter. Before being placed into the perforations in the planting tubes, the lettuce seedlings were planted in a plastic cup. Cooper (1979) proposed employing a nutrition solution with a suitable composition. Nutrient solution was usually maintained at a pH of 6.0–6.3 and an electrical conductivity (EC) of 1.5–2.0 mS/cm for optimum plant growth. Seven foliar spray treatments were performed on the 840 plants of the two hybrids produced by the hydroponic system (20 plants per treatment). Foliar spray treatments were utilized from the first week following transplanting and continued for a total of five weeks. During the experiment, the Cooper solution formula was used for the treatment of NFT (Cooper, 1979). The following substances were applied at the following quantities: 236 ppm N, 60 ppm P, 300 ppm K, 185 ppm Ca, 50 ppm Mg, 68 ppm S, 12 ppm Fe, 0.3 ppm B, 2 ppm Mn, 0.1 ppm Zn, 0.1 ppm Cu, and 0.2 ppm Mo (NFT).

Table (1). Average of relative humidity, temperature and wind speed in 2020 and 2021 seasons.

Year	Month	Relative humidity	Minimum temperature	Maximum temperature	Wind speed
2020	**Jan.**	70.94	15.12	21.48	7.06
	Feb.	75.31	15.08	23.74	6.32
	March	75.12	15.73	25.30	6.34
	April	75.19	16.96	27.11	4.82
	May	74.94	19.65	36.27	5.10
	June	75.12	21.75	36.78	5.16
	July	74.44	26.48	36.31	5.16
	Aug.	73.56	28.14	36.78	5.41
	Sep.	73.88	27.75	36.89	4.58
	Oct.	68.50	25.18	33.16	3.67
	Nov.	71.06	20.37	27.83	5.41
	Dec.	67.69	18.21	25.00	4.73
2021	**Jan.**	71.62	16.01	24.16	5.91
	Feb.	72.12	14.03	24.49	5.7
	March	72.75	15.37	26.16	6.05
	April	71.62	15.79	32.30	5.45
	May	72.75	21.51	37.22	4.34
	June	75.62	22.97	35.34	4.8
	July	74.12	27.23	38.05	5.6
	Aug.	74.56	28.55	37.75	5.47
	Sep.	71.62	28.65	38.11	5.62
	Oct.	62.06	23.69	36.23	4.57
	Nov.	69.56	20.71	30.49	4.59
	Dec.	67.44	15.40	24.59	6.15

2. Hydroponic Cultivation

2.1. A-shape metal triangle frame

An iron metal triangle frame with a 60-degree angle, a height of 130 cm, and a bottom width of 130 cm was used to construct the A-shape system. To create three levels on each side of the A-shaped triangular frame-35 cm for the bottom level, 25 cm for the middle level, and 25 cm for the top level-four gully holds were also linked to each side after burying 10 cm of each side in the ground. An A-shape system with a 1% slope towards the solution tank was constructed using four A-shaped triangular frames placed 2 m apart.

2.2. Gullies

After punching holes in the 6-meter PVC tubing, grooves were formed in this NFT system employing 110 mm grey polyvinyl chloride (PVC) tubing. The plastic cups were 9 cm in diameter and 11 cm in length, packed with holes.

2.3. Solution tank

A 5,000 L polyethylene tank that served as both a fertilizer solution tank and a collection tank was used to supply six gullies in each A-shaped system (one nutrient solution tank per A-shape system). Six gullies' outlets were placed inside the tanks, which were put in front of each A-shaped system (closed system).

2.4. Circulated solution system

The nutrient solution was pumped up the polyethylene tube (18 mm) to the top of the six gullies in each A-shape system using submersible pumps (2 HP) (one pump for each nutrient solution tank). Via gravity (1% slope), the nutrient solution returns to the solution tank (reservoir), where it is repumped to the gullies. To avoid precipitation, two separate containers were used to prepare stocks of the nutritive solution. The remaining chemicals necessary to make up the nutritious solution were contained in the second container, whereas the first bottle contained calcium nitrate and iron chalets (El Behairy, 1994).

2.5. Foliar spray treatments

- Aminototal 20% and thiamin, were sprayed onto the plants as foliar sprays :1, 2 and 3 cm^3/L of 20% free amino acids were applied.
- Thiamin was added at concentrations of 0.06, 0.08, and 0.1 g/L
- Control (without treatments)

2.6. Data collection

Five randomly chosen plants from each treatment were examined for the following characteristics: the number of leaves per head, leg height, head diameter, head fresh and dry weights, total yield, and its components (marketable and unmarketable), total chlorophyll (SPAD), and chemical compositions in leaves such as N, P, K, Ca, Mg, NO_3 and carbohydrates contents. Using a modified Kjeldahl method, the amount of nitrogen (N%) in dried lettuce head tissues was assessed (Horneck and Miller, 1998).

Phosphorus (P%) content in dried lettuce head tissues was determined by Watanabe and Olsen (1965). A Beckman Flame photometer was used to determine potassium content (K%) following the method outlined by Jackson (1973). The nitrate level (NO_3) was evaluated colorimetrically in mg/kg dry weight according to Cataldo et al. (1975). Total P content was measured colorimetrically in mg/100 g dry weight using the hydroquinone and sodium sulphite method (A.O.A.C., 2000). Total carbohydrates in lettuce were quantified using the Anthron method, as described by Mahadevan and Sridhar (1986). For extraction, dry materials were ground in a Mahadevan buffer (sodium citrate buffer, pH 6.8). Before being centrifuged for 15 minutes at 4000 rpm, the extracts were homogenized for three minutes. The total carbohydrates were then calculated using the supernatant. Using a Beckman Flame photometer, calcium (Ca%) and magnesium (Mg%) contents were measured using the method outlined by Jackson (1973).

3. Experimental Design and Statistical Analysis

The hybrids were in the main plot, while foliar spray was in the sub-main plot, in a split-plot design. For each treatment, three replicates were used. There were 20 plants in each sub-main treatment. Two hybrids (main plots) and seven foliar sprays (sub-plots) made up the total experimental plots, which were reproduced three times. To distinguish between means, the Least Significant Difference (LSD 5%) was calculated using Analysis of Variance (ANOVA) on the gathered data (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

1. Effect of Hybrids

Table (2) displays how different treatments affected the number of lettuce leaves per head. Sara hybrid struggled compared to Aviram hybrid. The two hybrids differed significantly from one another. Leg height, however, varied throughout the two fruitful seasons and did not significantly differ between the two hybrids. Hybrids had increased fresh and dry weights of heads, with Aviram barely surpassing Sara hybrid in the fresh weight and dry weight categories in the 2020 season. However, there was no discernible difference in the dry weight between the two hybrids for the 2021 season (Table 3).

There were no noticeable changes in head diameter between hybrids (Table 4). However, chlorophyll concentration in Aviram hybrid significantly rose in comparison to Sara hybrid in both seasons. The yield and its components (marketable and unmarketable) did not significantly different in the two hybrids (Table 5). Although the N% of Aviram hybrid was much higher than Sara hybrid. Little variation in the P% content between the two hybrids was observed in the two growth seasons (Table 6). The two hybrids K levels did not considerably differ from one another

(Table 7). On the other hand, Ca percent percentage in Sara hybrid was significantly lower than Aviram hybrid (Table 7). Even though Sara hybrid had a higher Mg than Aviram hybrid, the difference was not apparent until the 2021 season (Table 8). The two hybrids carbohydrate contents did not significantly differ in both seasons. Aviram hybrid had a lower NO_3 concentration than Sara hybrid (Table 9).

Table (2). Effect of hybrid, foliar treatments and interaction on the number of leaves per head and leg height of lettuce plants in 2020 and 2021 seasons.

Hybrids	**Treatments**	**Number of leaves per head**		**Leg height (cm)**	
		2020 season	**2021 season**	**2020 season**	**2021 season**
Aviram	Aminototal (1 cm^3/L)	29.45	30.65	14.11	12.32
	Aminototal (2 cm^3/L)	31.11	32.43	15.76	14.76
	Aminototal (3 cm^3/L)	33.16	34.24	17.43	16.76
	Thiamin (0.06 g/L)	28.71	27.21	12.54	13.65
	Thiamin (0.08 g/L)	30.62	31.73	14.32	13.43
	Thiamin (0.1 g/L)	32.23	33.42	16.54	16.22
	Control	18.44	17.12	11.23	10.32
Mean		29.10	29.54	14.56	13.92
Sara	Aminototal (1 cm^3/L)	27.23	28.65	12.11	13.55
	Aminototal (2 cm^3/L)	29.66	30.43	14.32	15.22
	Aminototal (3 cm^3/L)	31.33	32.12	16.54	17.65
	Thiamin (0.06 g/L)	26.21	27.23	13.54	14.32
	Thiamin (0.08 g/L)	28.19	29.43	13.45	15.43
	Thiamin (0.1 g/L)	30.81	30.32	16.66	16.22
	Control	17.55	16.12	10.33	9.11
Mean		27.28	27.75	13.85	14.50
Treatment means	Aminototal (1 cm^3/L)	28.34	29.65	13.11	12.93
	Aminototal (2 cm^3/L)	30.38	31.43	15.04	14.99
	Aminototal (3 cm^3/L)	32.24	33.18	16.98	17.21
	Thiamin (0.06 g/L)	27.46	27.22	13.04	13.98
	Thiamin (0.08 g/L)	29.405	30.58	13.88	14.43
	Thiamin (0.1 g/L)	31.52	31.87	16.6	16.22
	Control	17.99	16.62	10.78	9.71
L.S.D. at 5%	Hybrids	0.85	0.87	1.07	1.20
	Treatments	1.05	1.08	1.87	1.40
	Interaction	1.48	1.62	1.90	2.02

Table (3). Effect of hybrid, foliar treatments andinteraction on the head fresh weight and head dry weight of lettuce plants in 2020 and 2021 seasons.

Hybrids	Treatments	Head fresh weight (g/plant)		Head dry weight (g/plant)	
		2020 season	2021 season	2020 season	2021 season
Aviram	Aminototal (1 cm^3/L)	220.34	212.55	13.33	14.32
	Aminototal (2 cm^3/L)	237.56	224.54	5.66	15.34
	Aminototal (3 cm^3/L)	287.23	300.56	18.21	19.34
	Thiamin (0.06 g/L)	194.21	187.43	11.22	12.34
	Thiamin (0.08 g/L)	225.78	219.44	14.34	14.32
	Thiamin (0.1 g/L)	280.33	266.54	17.24	16.45
	Control	157.23	140.55	8.87	7.42
Mean		228.95	221.65	12.69	14.21
Sara	Aminototal (1 cm^3/L)	216.32	217.77	13.43	11.23
	Aminototal (2 cm^3/L)	231.31	227.89	14.54	14.45
	Aminototal (3 cm^3/L)	304.34	277.45	19.43	17.43
	Thiamin (0.06 g/L)	177.13	200.11	12.23	13.33
	Thiamin (0.08 g/L)	224.87	220.67	14.45	15.87
	Thiamin (0.1 g/L)	258.11	257.33	16.33	13.57
	Control	124.56	117.23	10.56	9.11
Mean		219.52	216.92	14.42	13.57
Treatment means	Aminototal (1 cm^3/L)	218.33	215.16	13.38	12.77
	Aminototal (2 cm^3/L)	234.43	226.21	10.1	14.89
	Aminototal (3 cm^3/L)	295.78	289.00	18.82	18.38
	Thiamin (0.06 g/L)	185.67	193.77	11.72	12.83
	Thiamin (0.08 g/L)	225.32	220.05	14.39	15.09
	Thiamin (0.1 g/L)	269.22	261.93	16.78	15.01
	Control	140.89	128.89	9.71	8.26
L.S.D. at 5%	Hybrids	2.72	2.50	0.81	0.71
	Treatments	3.63	3.20	0.92	0.83
	Interaction	4.10	3.72	0.98	0.97

Table (4). Effect of hybrid, foliar treatments and interaction on the head diameter, and total chlorophyll of lettuce plants in 2020 and 2021 seasons.

Hybrids	Treatments	Head diameter (cm)		Total chlorophyll (SPAD)	
		2020 season	2021 season	2020 season	2021 season
Aviram	Aminototal (1 cm^3/L)	11.13	10.33	33.22	31.54
	Aminototal (2 cm^3/L)	13.33	14.23	41.56	40.33
	Aminototal (3 cm^3/L)	15.55	16.66	45.78	46.32
	Thiamin (0.06 g/L)	10.44	9.43	30.86	28.56
	Thiamin (0.08 g/L)	12.54	13.56	36.34	37.34
	Thiamin (0.1 g/L)	14.56	15.67	42.56	43.76
	Control	7.67	8.23	23.45	21.98
Mean		12.17	12.58	36.25	35.69
Sara	Aminototal (1 cm^3/L)	10.34	10.44	31.39	29.11
	Aminototal (2 cm^3/L)	14.43	12.76	37.67	35.64
	Aminototal (3 cm^3/L)	16.34	17.89	43.65	45.82
	Thiamin (0.06 g/L)	9.33	10.36	28.93	26.71
	Thiamin (0.08 g/L)	13.55	13.82	33.59	32.82
	Thiamin (0.1 g/L)	15.67	15.82	40.83	39.91
	Control	8.87	7.58	19.54	20.59
Mean		12.64	12.66	33.65	32.94
Treatment means	Aminototal (1 cm^3/L)	10.73	10.38	32.30	30.32
	Aminototal (2 cm^3/L)	13.88	13.49	39.61	37.98
	Aminototal (3 cm^3/L)	15.94	17.27	44.71	46.07
	Thiamin (0.06 g/L)	9.88	9.89	29.89	27.63
	Thiamin (0.08 g/L)	13.04	13.69	34.96	35.08
	Thiamin (0.1 g/L)	15.11	15.74	41.69	41.83
	Control	8.26	7.90	21.49	21.28
L.S.D. at 5%	Hybrids	0.61	0.55	1.00	1.10
	Treatments	0.73	0.64	1.62	1.71
	Interaction	0.71	0.77	2.01	1.77

Table (5). Effect of hybrid, foliar treatments and interaction on yield, marketable yield, and unmarketable yield of lettuce plants in 2020 and 2021 seasons.

Hybrids	Treatments	Total yield (g/m^2)		marketable yield (g/m^2)		Unmarketable yield (g/m^2)	
		2020 season	2021 season	2020 season	2021 season	2020 season	2021 season
Aviram	Aminototal (1 cm^3/L)	6109.00	6029.00	5625.00	5515.00	484.00	514.00
	Aminototal (2 cm^3/L)	6849.00	6790.00	6545.00	6435.00	304.00	355.00
	Aminototal (3 cm^3/L)	7860.00	7724.00	7625.00	7455.00	235.00	269.00
	Thiamin (0.06 g/L)	4894.00	4829.00	4355.00	4294.00	539.00	535.00
	Thiamin (0.08 g/L)	6504.00	6424.00	6185.00	6085.00	319.00	339.00
	Thiamin (0.1 g/L)	7719.00	7802.00	7355.00	7423.00	364.00	379.00
	Control	730.00	752.00	75.00	68.00	655.00	684.00
Mean		5809.28	5764.28	5395.00	5325.00	414.28	439.28
Sara	Aminototal (1 cm^3/L)	6089.00	6002.00	5625.00	5515.00	464.00	487.00
	Aminototal (2 cm^3/L)	6695.00	6518.00	6350.00	6165.00	345.00	353.00
	Aminototal (3 cm^3/L)	7750.00	7601.00	7535.00	7360.00	215.00	241.00
	Thiamin (0.06 g/L)	5304.00	5228.00	4755.00	4694.00	549.00	534.00
	Thiamin (0.08 g/L)	6566.00	6473.00	6185.00	6084.00	381.00	389.00
	Thiamin (0.1 g/L)	7639.00	7616.00	7315.00	7295.00	324.00	321.00
	Control	666.00	688.00	72.00	69.00	594.00	619.00
Mean		5815.57	5732.28	5405.28	5311.71	410.28	420.57
Treatment means	Aminototal (1 cm^3/L)	6099.00	6015.50	5625.00	5515.00	474.00	500.50
	Aminototal (2 cm^3/L)	6772.00	6654.00	6447.50	6450.00	324.50	354.00
	Aminototal (3 cm^3/L)	7805.00	7662.50	7580.00	7407.50	225.00	225.00
	Thiamin (0.06 g/L)	5099.00	5028.50	4555.00	4494.00	544.00	534.50
	Thiamin (0.08 g/L)	6535.00	6448.50	6185.00	6085.00	350.00	364.00
	Thiamin (0.1 g/L)	7679.00	7709.00	7335.00	7359.00	344.00	350.00
	Control	698.00	720.00	73.50	68.50	624.50	651.50
L.S.D. at 5%	Hybrids	35.10	33.34	31.20	27.30	21.21	18.10
	Treatments	39.18	36.53	36.63	28.20	23.85	20.53
	Interaction	44.33	40.72	39.32	30.10	26.73	21.53

Table (6). Effect of hybrid, foliar treatments and interaction on nitrogen and phosphorus percentages in lettuce plants in 2020 and 2021 seasons.

Hybrids	**Treatments**	**N (%)**		**P (%)**	
		2020 season	**2021 season**	**2020 season**	**2021 season**
Aviram	Aminototal (1 cm^3/L)	3.80	3.55	0.38	0.35
	Aminototal (2 cm^3/L)	4.19	4.20	0.40	0.40
	Aminototal (3 cm^3/L)	4.93	4.87	0.48	0.44
	Thiamin (0.06 g/L)	3.50	3.21	0.37	0.34
	Thiamin (0.08 g/L)	4.08	4.16	0.40	0.37
	Thiamin (0.1 g/L)	4.59	4.36	0.43	0.40
	Control	3.24	3.29	0.29	0.26
Mean		4.04	3.94	0.39	0.36
Sara	Aminototal (1 cm^3/L)	3.52	3.09	0.36	0.35
	Aminototal (2 cm^3/L)	4.19	3.97	0.42	0.41
	Aminototal (3 cm^3/L)	4.37	4.00	0.47	0.45
	Thiamin (0.06 g/L)	3.22	3.92	0.36	0.35
	Thiamin (0.08 g/L)	4.07	4.01	0.40	0.40
	Thiamin (0.1 g/L)	4.25	4.06	0.41	0.39
	Control	2.78	2.95	0.28	0.27
Mean		3.77	3.71	0.38	0.37
Treatment means	Aminototal (1 cm^3/L)	3.66	3.32	0.37	0.35
	Aminototal (2 cm^3/L)	4.19	4.08	0.41	0.40
	Aminototal (3 cm^3/L)	4.65	4.43	0.47	0.25
	Thiamin (0.06 g/L)	3.36	7.13	0.36	0.34
	Thiamin (0.08 g/L)	4.07	2.08	0.4	0.38
	Thiamin (0.1 g/L)	4.42	4.21	0.42	0.39
	Control	3.01	3.12	0.28	0.26
L.S.D. at 5%	Hybrids	0.14	0.16	0.07	0.04
	Treatments	0.24	0.27	0.05	0.01
	Interaction	0.37	0.39	0.06	0.02

Table (7). Effect of hybrid, foliar treatments and interaction on potassium and calcium percentages in lettuce plants in 2020 and 2021 seasons.

Hybrids	Treatments	K (%)		Ca (%)	
		2020 season	2021 season	2020 season	2021 season
Aviram	Aminototal (1 cm^3/L)	5.17	5.36	0.94	0.94
	Aminototal (2 cm^3/L)	6.22	6.10	1.18	1.10
	Aminototal (3 cm^3/L)	7.09	7.03	1.60	1.65
	Thiamin (0.06 g/L)	4.92	4.82	0.90	0.94
	Thiamin (0.08 g/L)	5.73	5.42	0.98	1.01
	Thiamin (0.1 g/L)	6.51	6.40	1.37	1.20
	Control	4.32	4.19	0.80	0.80
Mean		5.70	5.61	1.11	1.18
Sara	Aminototal (1 cm^3/L)	5.28	5.14	0.89	0.91
	Aminototal (2 cm^3/L)	6.11	5.96	1.19	0.99
	Aminototal (3 cm^3/L)	7.08	6.92	1.61	1.45
	Thiamin (0.06 g/L)	4.40	4.32	0.89	0.86
	Thiamin (0.08 g/L)	5.90	5.85	0.97	1.00
	Thiamin (0.1 g/L)	6.40	6.13	1.10	1.16
	Control	4.36	4.16	0.79	0.80
Mean		5.64	5.49	1.06	1.02
Treatment means	Aminototal (1 cm^3/L)	5.22	5.25	0.915	0.925
	Aminototal (2 cm^3/L)	6.16	6.03	1.18	1.04
	Aminototal (3 cm^3/L)	7.08	6.97	1.60	1.55
	Thiamin (0.06 g/L)	4.66	4.57	0.89	0.9
	Thiamin (0.08 g/L)	5.81	5.63	0.97	1.005
	Thiamin (0.1 g/L)	6.455	6.26	1.235	1.18
	Control	4.34	4.17	0.79	0.80
L.S.D. at 5%	Hybrids	0.22	0.18	0.01	0.01
	Treatments	0.34	0.30	0.02	0.02
	Interaction	0.40	0.37	0.05	0.04

Table (8). Effect of hybrid, foliar treatments and interaction on magnesium and carbohydrate percentages in lettuce plants in 2020 and 2021 seasons.

Hybrids	Treatments	Mg (%)		Carbohydrate (%)	
		2020 season	**2021 season**	**2020 season**	**2021 season**
Aviram	Aminototal (1 cm^3/L)	0.40	0.41	11.11	11.34
	Aminototal (2 cm^3/L)	0.50	0.52	13.04	13.20
	Aminototal (3 cm^3/L)	0.60	0.61	14.82	14.72
	Thiamin (0.06 g/L)	0.37	0.37	11.82	11.73
	Thiamin (0.08 g/L)	0.45	0.45	12.71	12.40
	Thiamin (0.1 g/L)	0.52	0.53	14.29	14.36
	Control	0.34	0.32	8.48	7.88
Mean		0.45	0.48	22.36	12.23
Sara	Aminototal (1 cm^3/L)	0.37	0.36	11.84	11.60
	Aminototal (2 cm^3/L)	0.48	0.49	13.60	13.28
	Aminototal (3 cm^3/L)	0.58	0.57	14.90	14.77
	Thiamin (0.06 g/L)	0.34	0.33	11.70	11.62
	Thiamin (0.08 g/L)	0.41	0.39	12.30	12.53
	Thiamin (0.1 g/L)	0.49	0.47	14.46	14.34
	Control	0.28	0.29	7.78	8.08
Mean		0.42	0.41	12.36	12.31
Treatment means	Aminototal (1 cm^3/L)	0.38	0.38	11.47	11.47
	Aminototal (2 cm^3/L)	0.49	0.50	13.32	13.24
	Aminototal (3 cm^3/L)	0.59	0.59	14.86	14.74
	Thiamin (0.06 g/L)	0.355	0.35	11.76	11.675
	Thiamin (0.08 g/L)	0.43	0.42	12.505	12.46
	Thiamin (0.1 g/L)	0.505	0.5	14.37	14.35
	Control	0.31	0.305	8.13	7.98
L.S.D. at 5%	Hybrids	0.01	0.02	0.49	0.46
	Treatments	0.02	0.03	0.65	0.50
	Interaction	0.04	0.05	0.67	0.55

Table (9). Effect of hybrid, foliar treatments and interaction on nitrate content of lettuce plants in 2020 and 2021seasons.

Hybrids	Treatments	Total NO_3 content (mg/kg d.wt.)	
		2020 season	2021 season
Aviram	Aminototal (1 cm^3/L)	101.13	98.70
	Aminototal (2 cm^3/L)	95.74	94.19
	Aminototal (3 cm^3/L)	90.15	91.46
	Thiamin (0.06 g/L)	109.57	104.34
	Thiamin (0.08 g/L)	102.22	101.49
	Thiamin (0.1 g/L)	92.35	90.12
	Control	206.33	203.45
Mean		113.92	111.96
Sara	Aminototal (1 cm^3/L)	107.38	103.16
	Aminototal (2 cm^3/L)	102.93	98.34
	Aminototal (3 cm^3/L)	97.05	93.91
	Thiamin (0.06 g/L)	100.52	106.46
	Thiamin (0.08 g/L)	95.14	101.15
	Thiamin (0.1 g/L)	88.03	96.25
	Control	208.34	204.48
Mean		114.19	114.82
Treatment means	Aminototal (1 cm^3/L)	104.25	100.93
	Aminototal (2 cm^3/L)	99.33	96.26
	Aminototal (3 cm^3/L)	93.60	92.68
	Thiamin (0.06 g/L)	105.05	105.4
	Thiamin (0.08 g/L)	98.68	101.32
	Thiamin (0.1 g/L)	90.19	93.18
	Control	207.33	203.97
L.S.D. at 5%	Hybrids	2.10	3.03
	Treatments	3.14	4.05
	Interaction	4.30	5.08

2. Effect of Foliar Treatments

All applied treatments significantly enhanced the quantity of leaves per head in both seasons as compared to the control treatment (Table 2). Also, all amino acid therapies showed a sizable benefit above thiamin therapy. However, only the highest dosage of each medication influenced leg height. In all seasons, the effects of all treatments, including amino acids, were greater than those of thiamin therapies on fresh and dry head weights (Table 3). However, only amino acid (2.0 cm/L) and thiamin (1.0 cm/L) had a negligible difference in dry weight. Head diameter (Table 4) responded favorably and considerably to each foliar spray treatment when compared to control. The highest dose of amino acids was used to produce the maximum head diameter when compared to the other foliar treatments. In comparison to the control, the chlorophyll content was significantly higher after each foliar spray application (Table 4).

When compared to all other therapies, amino acid injection at the maximum dose produced the most favorable outcomes. Comparative to the control treatment, the overall yield increased with each foliar treatment (Table 5). The total yield dramatically rose as the foliar doses of each chemical increased. Amino acid therapies performed better than thiamin therapies. Contrarily, the yield from the control treatment was entirely unmarketable. Each foliar spray treatment considerably increased marketable yield. Comparing all foliar spray treatments to the control treatment, the N and P content in growing plants increased significantly (Table 6).

The highest concentration of amino acids produced the greatest benefit, whereas the lowest concentration of thiamin produced the greatest disadvantage. Similar amounts of thiamin and moderate and medium doses of amino acids both exhibited comparable effects on P percentage. Amounts of thiamin or amino acids that were noticeably higher than others were only found in the highest dose. K and Ca% were significantly raised by all foliar spray treatments, with the maximum benefit seen under the highest dose of amino acids, followed by the highest dose of thiamin (Table 7). Significant responses to all foliar spray treatments were also seen for Mg and carbohydrates percentages (Table 8). Furthermore, these benefits were more potent as the application dose was raised. The impact of amino acids had the biggest effects (3.0 cm^3/L). The foliar spray treatments had no impact on anything, except NO_3 levels (Table 9). When compared to the control treatment, all foliar spray treatments reduced the concentration of NO_3. In amino acids, the greatest decrease (3 cm^3/L) was observed. Both research seasons resulted in these findings.

3. Effect of Interaction

There was an interaction between hybrids and treatments for the number of leaves per head vs. leg height (Table 2). Treatments with amino acids had a greater impact on Aviram hybrid than thiamin treatments had on

Sara hybrid. However, all treatments were significantly more expensive than the control. Hybrids and amino acid doses effect on fresh and dry weights had a p-value interaction in both seasons. On the other hand, Aviram hybrid responded most favorably to the largest dosage of amino acids (Table 3). The head diameter was affected by the foliar application treatments (Table 4), with the highest dose of amino acids (3 cm^3/L) resulting in the biggest head diameter compared to the control. In Aviram hybrid, compared to Sara hybrid, all foliar spray treatments resulted in a higher chlorophyll concentration. However, in contrast to all other treatments, Aviram hybrid with the highest amino acid concentration had the greatest amount of chlorophyll. The substantial reaction in this parameter was more comparable to what was seen with foliar spray treatments because hybrids had no impact on yield (Table 5).

The positive response to amino acids was the highest in both hybrids with 3 cm^3/L, thiamin, however, had the lowest favorable reaction at 0.06 g/L. Like the foliar spray treatments, the marketable yield improved dramatically (Table 5). When compared to the other treatments, Aviram hybrid, which had the highest amino acid content, had the best yield. The treatments with the highest levels of thiamin and amino acids resulted in a great variation in terms of N percentage within each hybrid (Table 6). In comparison to the control, each foliar treatment significantly enhanced the P percentage in both hybrids (Table 6). For K and Ca content, there was a p-value interaction between foliar treatments and hybrids. Compared to all other treatments, the highest amino acid dosage significantly affected K and Ca levels in both hybrids (Tables 6 and 7). For Mg and carbohydrate percentages, the interactions between amino acids and hybrids were advantageous (Table 8). The amino acid therapy on Aviram hybrid resulted in the lowest NO_3 levels compared to all other treatments (Table 9).

Lettuce loves a temperature range of 4°C to 27°C despite being able to withstand temperatures as high as 30°C (Puiatti and Finger, 2005). The results show that high temperatures significantly diminish the marketable lettuce of Aviram and Sara hybrids. For this originally temperate plant, developing heat-tolerant genotypes is the key problem, yet hybrids little affect this feature (Queiroz et al., 2014). In comparison to the control, foliar sprays of thiamin and amino acids enhanced all aspects of plant growth and quality. Other crops grown in stressful environments have demonstrated to benefit from amino acid treatments (Kowalczyk et al., 2008 and Tantawy et al., 2009). Because they are bio stimulants (Rouphael and Colla, 2018 and Rouphael et al., 2018), they protect cells from abiotic stress damage (Kowalczyk et al., 2008), and they act as precursors to hormones, amino acids may have these positive (Kowalczyk et al., 2008; Calvo et al., 2014; Rouphael and Colla, 2018 and Rouphael et al., 2018). The improved plant performance seen in this study could be attributed to any one of these factors. Additionally, the possible effect of amino acids on root development

(Walch-Liu and Forde, 2007; Calvo et al., 2014 and Halpern et al., 2015) and function (Hildebrandt et al., 2015 and Weiland et al., 2016) can be the reason for improved nutrient content in plant tissue, which was reflected in the total plant production and quality in the current study. Alternatively, stress conditions (including heat stress) can interrupt essential compounds' metabolic processes by harming growing plants, for example, Hanson et al. (2016) mentioned that abiotic stresses cause vitamin and cofactor deficiencies, degrading plant performance. They concluded that supplementing stressed plants with deficient vitamin(s) improves their performance. This finding explains the observed positive effects of applying thiamin in this study. In previous studies, applying thiamin to stressed crop species has also been reported to have beneficial effects on plants under salinity stress, e.g., wheat, sunflower, and corn (Al-Hakimi and Hamada, 2001; Sayed and Gadallah, 2002 and Kaya et al., 2015). However, Asensi-Fabado and Munné-Bosch (2010) stated that it is uncertain if the observed protection is due to the direct actions of vitamins. Nevertheless, differences between hybrids due to genetic hybrid differences are proposed to affect the results in this investigation.

CONCLUSION

It can be assumed that adding thiamin and amino acids to hydroponic systems will increase lettuce productivity and quality. The Aviram hybrid had the best outcomes when given the highest dosage of thiamin and amino acids. Contrarily, under the control treatment, lettuce output and quality were at their lowest (without amino acids and thiamin). Future investigation might focus on mixing the two compounds, which might have positive additive effects.

REFERENCES

Abdel-Mawgoud, A.M.R. (1995). Effect of shade on the growth and yield of tomato plants. Acta Horticulturae, 434: 313- 320.

Al-Hakimi, A. and A.M. Hamada (2001) Counteraction of salinity stress on wheat plants by grain soaking in ascorbic acid, thiamin or sodium salicylate. Biologia Plantarum, 44: 253-261.

A.O.A.C. (2000). In: ‘Official Methods of Analysis of A.O.A.C International’. 17th Ed., USA.

Asensi-Fabado, M.A. and S. Munné-Bosch (2010) Vitamins in plants: occurrence, biosynthesis and antioxidant function, Trends in Plant Science, 15: 582-592.

Calvo, P., L. Nelson and J. Kloepper (2014). Agricultural uses of plant biostimulants. Plant and Soil, 383: 3-41.

Cataldo, D.A., M. Haroon, L.E. Schrader and V.L. Youngs (1975). Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. Communications in Soil Science and Plant Analysis, 6 (6): 71-80.

Choi, K.Y. and Y.B. Lee (2004). Effect of air temperature on tip burn incidence of butterhead and leaf lettuce in a plant factory. Journal of the American Society for Horticultural Science, 44: 805-808.

Cooper, A. (1979). In: 'The ABC of NFT: Nutrient Film Technique'. Grower Book, London.

El Behiary, U.A. (1994). The effect of levels of phosphorus and zinc in the nutrient solution on macro and micronutrients uptake and translocation in cucumber *(Cucumus sativus* L.) grown by the nutrient film technique. PhD Thesis, London University, 299 p.

Fukuda, M., S. Matsuo, K. Kikuchi, W. Mitsuhashi, T. Toyomasu and I. Honda (2012). Gibberellin metabolism during stem elongation stimulated by high temperature in lettuce. Acta Horticulturae, 932: 359-364.

Halpern, M., A. Bar-Tal, M. Ofek, D. Minz, T. Muller and U. Yermiyahu (2015). The Use of Biostimulants for Enhancing Nutrient Uptake. In: 'Sparks, D.L. (Ed.)', Advances in Agronomy. Academic Press, New York, USA, pp. 141-174.

Hanson, A.D., G.A. Beaudoin, D.R. McCarty and J.F. Gregory (2016). Does abiotic stress cause functional B vitamin deficiency in plants? Journal of Plant Physiology, 172: 2082-2097.

Hildebrandt, T.M., A.N. Nesi, W.L. Araújo and H.P. Braun (2015). Amino acid catabolism in plants. Molecular Plant, 8: 1563-1579.

Horneck, D.A. and R.O. Miller (1998). Determination of Total Nitrogen in Plant Tissue. In: 'Kalra, Y.P. (Ed.)', Handbook of References Methods for Plant Analysis. Soil and Plant Analysis Council, Inc. CRC Press, Boca Raton, pp. 75-83.

Jackson, M.L. (1973). In: 'Soil Chemical Analysis'. Prentice Hall of India Private Limited, New Delhi, 498 p.

Kaya, C., M. Ashraf, O. Sonmez, A.L. Tuna, T. Polat and S. Aydemir (2015). Exogenous application of thiamin promotes growth and antioxidative defense system at initial phases of development in salt-stressed plants of two maize cultivars differing in salinity tolerance. Acta Physiologiae Plantarum, 37: 1741.

Khan, S., H. Yu, Q. Li et. al. (2019). Exogenous application of amino acids improves the growth and yield of lettuce by enhancing photosynthetic assimilation and nutrient availability. Agronomy, 9: 266.

Kowalczyk, K., T. Zielony and M.E. Gajewski (2008). Effect of Aminoplant and Asahi on yield and quality of lettuce grown on rockwool. Biostimulators in Modern Agriculture, 2 (111): 35-43.

Mahadevan, A. and R. Sridhar (1986). In: 'Methods in Physiological Plant Pathology'. Sirakami Publications, 326 p.

Puiatti, M. and F.L. Finger (2005). Fatores climáticos. In: 'Fontes, P.C.R. (Ed.)', Olericultura Teoria e Prática. Suprema, Rio Branco, Brasil, pp. 17-38.

Queiroz, J.P., S. da, A.J.M. Costa, L.G. da Neves, S.S. Junior and M.A.A. Barelli (2014). Phenotypic stability of the lettuce in different periods and cropping environments. Revista Ciência Agronômica, 45 (2): 276-283.

Rader, H.B. and M.G. Karlsson (2006). Northern field production of leaf and romaine lettuce using a high tunnel. HortTechnology, 16: 649-654.

Romani, A., P. Pinelli, C. Galardi, G. Sani, A. Cimato and D. Heimler (2002). Polyphenols in greenhouse and open-air-grown lettuce. Food Chemistry, 79: 337-342.

Rouphael, Y. and G. Colla (2018). Synergistic biostimulatory action: Designing the next generation of plant biostimulants for sustainable agriculture. Frontiers in Plant Science, 9: 1655.

Rouphael, Y., L. Spíchal, K. Panzarová, R. Casa and G. Colla (2018). High-throughput plant phenotyping for developing novel biostimulants: From lab to field or from field to lab. Frontiers in Plant Science, 9: 1197.

Sayed, S.A. and M.A. Gadallah (2002). Effects of shoot and root application of thiamin on salt-stressed sunflower plants. Plant Growth Regulation, 36: 71-80.

Simonne, A., E. Simonne, R. Eitenmiller and C.H. Coker (2002). Bitterness and composition of lettuce varieties grown in the southeastern United States. HortTechnology, 12: 721-726.

Snedecor, G.W. and W.G. Cochran (1980). In: 'Statistical Method'. 7th Ed., The Lowa State College Press, Iowa State, USA, pp. 255-269.

Tantawy, A.S., A.M.R. Abdel-Mawgoud, M.A. El-Nemr and Y.C. Ghorra (2009). Alleviation of salinity effects on tomato plants by application of amino acids and growth regulators. European Journal of Scientific Research, 30 (3): 484-494.

Thakulla, D., B. Dunn, B. Hu, C. Goad and N. Maness (2021). Nutrient solution temperature affects growth and Brix parameters of seventeen lettuce cultivars grown in an NFT hydroponic system. Horticulturae, 7 (9): 321-330.

Thompson, H.C., R.W. Langhans, A. Both and L.D. Albridght (1998). Shoot and root temperature effects on lettuce growth in a floating hydroponic system. Journal of American Society for Horticultural Science, 123: 361-364.

Walch-Liu, P. and B.G. Forde (2007). L-glutamate as a novel modifier of root growth and branching: Whats the sensor? Plant Signaling and Behavior, 2: 284-286.

Watanabe, F.S. and S.R. Olsen (1965). Test of an ascorbic acid method for determine phosphorus in water and Na HCO_3 extracts from soil. Proceedings in the Soil Science Society of America, 29: 677-678.

Waycott, W. (1995). Photoperiodic response of genetically diverse lettuce accessions. The Journal of the American Society for Horticultural Science, 120: 460-467.

Weiland, M., S. Mancuso and F. Baluska (2016). Signalling via glutamate and GLRs in *Arabidopsis thaliana*. Functional Plant Biology, 43: 1-25.

Wurr, D.C.E., J.R. Fellows and K. Phelps (1996). Investigating trends in vegetable crop response to increasing temperature associated with climate change. Scientia Horticulturae, 66: 255-263.

Zhao, X. and E.E. Carey (2009). Summer production of lettuce, and microclimate in high tunnel and open field plots in Kansas. HortTechnology,19: 113-119.

تأثير بعض المعاملات العضوية على تحمل نباتات الخس الكابوتشا لدرجات الحرارة العالية تحت نظام الزراعة الهيدروبونيك

ياسر عبد الحكيم محمد سلامة

قسم الأصول الوراثية، شعبة البيئة وزراعات المناطق الجافة، مركز بحوث الصحراء، القاهرة، مصر

تناولت هذه الدراسة تأثير الرش الورقي للأحماض الأمينية والثيامين على محصول وجودة الخس (*Lactuca sativa* L.) في صيف ٢٠٢٠ و٢٠٢١ باستخدام طريقة الزراعة المائية تم زراعة عدد ٢ هجين خس أفيرام وسارة. وتم إجراء المعاملات لمدة خمسة أسابيع بمعدل مرة واحدة في الأسبوع أمينوتوتال ٢٠٪ أحماض أمينية حرة والثيامين وذلك بتركيزات١، ٢، ٣ سم^{٣}/لتر و٠.٠٦، ٠.٠٨، ٠.١ جم/لتر، على التوالي. حسنت جميع معاملات الرش الورقي نمو النباتات عند مقارنتها بالغير معاملة وازداد محتوى النيتروجين والفسفور والبوتاسيوم والكالسيوم والماغنسيوم في النباتات المعاملة. تأثر إنتاج هجين أفيرام القابل للتسويق والمحصول الكلي بوضوح بمعاملة الرش الورقي بأعلى تركيز من الأحماض الأمينية على العكس من ذلك أوضحت النباتات الغير معاملة المقارنة انخفاض المحصول الكلي والقابل للتسويق لرؤوس الخس بدون الأحماض الأمينية والثيامين.