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Improving Growth and Productivity of Safflower (*Carthamus tinctorius* L.) Plant by Utilizing L-Tryptophan and Phenylalanine Acids under Different Potassium Fertilizer Rate

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ABSTRACT

In order to improve growth, yield components and chemical constituents of safflower plants a field experiment was done at a privet farm in Mansoura, Dakahlia Governorate, Egypt, during winter seasons of 2021/2022 and 2022/2023. Two factors in this experiment were examined, potassium rate (0.0, 24, 48 and 72 kg K_2O/feddan) and amino acids types (control, L-tryptophan, phenylalanine and L-tryptophan + phenylalanine each at 150 ppm) as well as their combination treatments. The achieved results indicated that increasing potassium fertilizer rates gradually increased plant height, branch number per plant and total dry weight of safflower, seed yield per plant and /feddan and fixed oil and petals yields per feddan as well as total chlorophyll contents and carthamin content. The highest values in this regard were obtained when plants fertilized with 72 kg K_2O/feddan compared to the other rates under study. In addition, utilizing L-tryptophan + phenylalanine each at 150 ppm significantly increased growth and productivity of safflower plants compared to control (un-sprayed plants) and each one individually. Generally, the best combination treatment for improving seed, fixed oil and carthamin yields were achieved with the treatment of L-tryptophan acid + phenylalanine each at 150 ppm and fertilized with 72 kg K_2O/feddan.

***Keywords*: Safflower, K-fertilizer, amino acids, fixed oil, carthamin**

INTRODUCTION

The annual herbaceous plant known as safflower (*Carthamus tinctorius* L.) is suited for hot, dry climates (Li and Mundel, 1996). The sunflower originated in Asia. This versatile oilseed plant is mostly grown for its superior oil quality, but it is also produced for cut flowers and vegetables. The majority of genotypes of this 30- to 150-cm-tall plant have numerous sharp spines on its leaves and bracts. It is thought to be a drought-tolerant plant since it can absorb moisture at levels that most crops cannot (Weiss, 2000). Safflower classifies as a plant that can withstand moderate amounts of salt. According to Koutroubas and Papadoska (2005), safflower plants can also be cultivated effectively in regions with relatively low temperatures and in soil that is not very fertile.

Because it facilitates osmotic control, phloem transport, and photosynthesis, potassium (K) is essential for plants (Tripler *et al*., 2006). Another advantage of these nutrients is that they increase plant yields by improving the plants' capacity to utilize nutrients. Minerals like potassium (K), which is utilized by plants to create numerous processes, may have an impact on the growth and synthesis of essential oils in aromatic plants. The function and concentrations of the enzymes involved in the manufacture of terpenoides are impacted by this mineral (Hafsi *et al*., 2014).

For the stimulation of cell development, amino acids are especially important. Their dual acidic and basic groups function as buffers, assisting in the preservation of a suitable pH level within the plant cell. Though amino acid foliar sprays are increasingly being used, their exact purpose is still unclear (Hadi *et al*., 2011). In order to eliminate ammonia from the cell, they shield plants from ammonia toxicity. Vitamins, pigments, alkaloids, purine and pyrimidine bases, enzymes, coenzymes, and terpenoids are among the various organic molecules that require amino acids for their formation. Plant exudates that include L-tryptophan, the precursor to IAA, are found in nature (Quiroz-Villareal *et al*., 2012). Previous research has demonstrated that amino acids can affect a plant's physiological activity either directly or indirectly (Sadaghiani *et al*., 2019).

The present study was performed to determine the influence of different rates of potassium fertilizer as well as different type of L-tryptophan and phenylalanine on safflower growth, yield components, fixed oil and total chlorophyll content of safflower plants.

MATERIALS AND METHODS

At a private Farm in Mansoura, Dakahlia Governorate, Egypt, a field experiment was successfully carried out during the two succeeding winter seasons of 2021/2022 and 2022/2023. This study looked at the effects of various potassium fertilization rates (0.0, 24, 48, and 72 kg K2O/feddan), various amino acid types [L-tryptophan acid (Trp) at 150 ppm and phenylalanine acid (Phe) at 150 ppm, Trp + Phe each at 150 ppm and tap water was sprayed as a control], and their combinations on the growth, yield, and components of the safflower plant (*Carthamus tinctorius* L.), as well as the total chlorophyll content, potassium percentage and carthamin content.

Seed source and sowing methods

Safflower seeds were procured from the Research Centre of Medicinal and Aromatic Plants, located in Dokky,

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Giza. The seeds were planted on October 12th, 2021/2022, and October 9th, 2022/2023. After sowing the seeds at a distance of 30 cm, irrigation was started right away. The seedlings were thinning to one plant per hill after three weeks of seeding. The experimental plot, which measured 25.20 m2 (4.00 × 6.30 m), had nine ridges, each measuring 4 m in length and 70 cm apart. The physical and chemical properties of the experimental farm soil site are shown in Table 1 according to (Chapman and Pratt, 1978).

Table 1. Physical and chemical properties of experimental farm soil (average of two seasons)

Mechanical analysis			Soil texture
Clay (%)	Silt (%)	Sand (%)	Loamy
45.68	28.78	25.54	

Chemical analysis													
pH	E.C. (dsm^{-1})	Soluble cations (m.mol/l)						Soluble anions (m.mol/l)			Available (ppm)		
		Ca^{++}	Mg^{++}	Na^{+}	Fe	Zn^{++}	Mo^{++}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.80	1.72	2.14	2.91	1.20	0.41	1.35	1.55	3.48	4.38	1.70	142	120	64

Fertilization

Potassium sulphate (48% K_2O) was applied to the soil three times a season at varied rates of potassium (0.0, 24, 48, and 72 kg of K_2O/feddan). Calcium superphosphate (15.5% P_2O_5) used as the source of phosphorus, while ammonium sulphate (20.5% N) provided nitrogen. During soil preparation, all of the phosphorus fertilizer was added. Conversely, three equal rates of potassium and nitrogen fertilizers were added to the soil at 35, 55, and 75 days following the date of seeding.

Amino acids source and application:

TECHNO GENE Company, Dokky, Giza, Egypt, was the source of both phenylalanine acid [(S)-2-Amino-3-phenylporpionic acid ($C_9H_{11}NO_2$)] and L-tryptophan acid [(S)-2-Amino-3-(3-indolyl) porpionic acid ($C_{11}H_{12}N_2O_2$). After the planting date, the amino acid type treatments foliarly applied at 40, 60, and 80 days. Five letters of solution were given to each experimental unit using Super Film as the spreading agent at a rate of one milliliter per liter. Tap water was used together with a spreading agent to spray the unsprayed control plants. All normal agricultural practices of growing safflower plants were applied whenever necessitated.

Experimental Design:

Three replicates were used in a split-plot design for this investigation. Four K rates occupied the principal plots. There were four categories of amino acids assigned to the subplots. There were sixteen treatments in the combination of K fertilization rates and amino acid types.

Sampling and Collecting Data:

Growth parameters

Three randomly selected plants were selected from each plot after 100 days of sowing in order to measure the following growth parameters: Plant height (cm), number of branches per plant and total dry weight of herb (g) were determined.

Yield and its components

At the harvesting stage, the yield of seeds and dry petals per plant (g) was calculated, and for the safflower plants, the production of seeds and petals per feddan (kg) was calculated as well. Using a soxcelt system HT apparatus and petroleum ether, seed fixed oil of safflower was extracted in accordance with A.O.A.C. (1984) techniques. Calculations were made for oil percentage, oil yield per plant (g), and oil yield per feddan (kg).

Chemical analysis:

Fresh leaves of safflower were measured for total chlorophyll content (SPAD unit) using the SPAD-502 meter, as described by Markwell *et al*. (1995). For the potassium percentage, a sample of safflower seeds was randomly selected from each treatment. In addition, total potassium (%) in seeds was calculated using the procedures outlined by Chapman and Pratt (1978). Moreover, the technique outlined by Harborne (1973) was used to determine the carthamin content (mg/100g).

Statistical Analysis

This experiment used a split-plot statistical layout with a complete randomized block design. In accordance with Gomez and Gomez (1984), data analysis was done. The Statistix version 9 computer application (Analytical software, 2008) was used to compare the means.

RESULTS AND DISCUSSION

Growth parameters

The data illustrated in Table 2 reveal that using any potassium fertilization rate significantly increased safflower growth parameters compared to control in 2021/2022 and 2022/2023 seasons. The highest values in this concern were obtained from 72 kg K_2O/ feddan. In general, this rate recorded the tallest safflower plants (129.00 and 128.67 cm), more branches (11.67 and 11.00 branches / plant) and the heaviest plant weight (130.32 and 127.10 g/ plant in the 1st and 2nd seasons, respectively. Potassium may be an exchangeable ion in the soil that plants actively absorb through their roots. It is a crucial nutrient for all types of soil and is most recently produced by the weathering of parent materials in the soil, such as soil potassium-aluminum silicates (Wiedenhoeft, 2006). According to Hafsi *et al.* (2014), potassium affects the activity and rates of enzymes involved in the production of carbohydrates. These results are in line with those reporwted by Ezz El-Din *et al.* (2010) on caraway, Nassar *et al.* (2015) on thorn apple plants, Mishra *et al.* (2016) on coriander and Massoud *et al.* (2019) on caraway.

Because of the different types of L-tryptophan and phenylalanine acid during the two seasons, there was a noticeable change in the height of the safflower plants, the number of branches per plant, and the total dry weight (Table 2). Accordingly, in both seasons, treatment with 150 ppm of L-tryptophan and phenylalanine boosted plant growth parameters in comparison to control. This improve was significant compared to control during the 1st and 2nd seasons. However, Omer *et al.* (2013) pointed out that the addition of amino acids significantly increased plant height and number of branches of chamomile plant compared to control (un-sprayed plants). Also, Youssef (2014) on *Echinacea*, Wahba *et al.* (2015) on *Urtica* and Ali *et al.* (2020) on roselle found similar results.

Table 2. Influence of potassium rate, amino acid type and their combination treatments on growth traits of safflower plant during 2021/2022 and 2022/2023 seasons

Treatments		Plant height(cm)		Number of branches/plant		Total dry weight /plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Potassium fertilizer rate (K_2O kg/feddan)							
0.0		108.50	108.33	8.25	8.17	103.22	101.89
24		114.33	124.08	10.75	9.58	125.72	111.10
48		122.75	114.92	9.17	8.92	110.07	123.50
72		129.00	128.67	11.67	11.00	130.32	127.10
LSD 5%		3.15	1.28	0.58	0.85	1.76	1.60
Amino acid type (150 ppm)							
Control		110.75	110.00	8.42	8.08	107.23	105.67
Tryptophan (Trp)		122.08	123.08	9.75	9.00	118.08	117.80
Phenylalanine (Phe)		115.42	117.33	9.58	9.17	116.00	114.26
Trp + Phe		126.33	125.58	12.08	11.42	128.02	125.77
LSD 5%		1.96	1.46	0.68	0.51	1.57	1.20
Combination influence							
0.0	Control	102.33	101.67	6.67	7.33	91.83	92.50
	Trp	110.00	113.00	7.67	7.33	102.83	103.77
	Phe	104.67	106.67	8.67	8.33	106.63	103.63
	Trp + Phe	117.00	112.00	10.00	9.67	111.57	107.67
24	Control	109.33	108.67	7.33	7.67	104.63	104.03
	Trp	118.33	117.33	9.00	9.00	109.57	112.93
	Phe	110.33	114.00	8.67	8.33	107.37	106.93
	Trp + Phe	119.33	119.67	11.67	10.67	118.73	120.50
48	Control	114.67	113.33	9.67	8.00	112.73	109.73
	Trp	126.00	127.67	10.67	8.67	128.67	126.13
	Phe	119.00	121.67	9.67	9.00	121.90	121.20
	Trp + Phe	131.33	133.67	13.00	12.67	139.57	136.93
72	Control	116.67	116.33	10.00	9.33	119.73	116.43
	Trp	134.00	127.00	11.67	11.00	131.27	128.37
	Phe	127.67	134.33	11.33	11.00	128.10	125.27
	Trp + Phe	137.67	137.00	13.67	12.67	142.20	137.97
LSD 5%		4.62	2.82	1.31	1.22	3.23	2.61

The results in Table 2 indicate that, in matter of combination effect, it was cleared that the highest values on safflower plant growth were obtained due to 72 K_2O kg /feddan combined with 150 ppm of L- tryptophan + phenylalanine during both seasons. Also, there was significant increase in this connection due to the combination treatments if compared to control (sprayed with tap water) when combined with 0.0 K rate during the two consecutive seasons. Additionally, as was previously mentioned, K fertilization and various amino acid types, when used separately, increased plant height, branch count per plant, and total dry weight of safflower plants. When combined, these effects may be maximized, resulting in the tallest, most branches per plant, and heaviest dry weight of safflower plants.

Yield and its components

The results listed in Table 3 show that in both seasons, seed yield per plant and the amount of petals produced per plant (g) and seed, petal and fixed oil yield per feddan grew steadily with increasing potassium fertilization rates. When compared to control, safflower yield components were significantly higher in plants that had received 72 kg K_2O/feddan. In the same trend, Ibrahim (2019) indicated that treated chamomile plants with potassium fertilizer (especially 100 kg potassium sulphate /feddan) induced significant increases in yield components (dry flower heads yield/plant and /feddan, yearly) compared to control.

Table 3 shows that L- tryptophan + phenylalanine treatment at 150 ppm followed by 150 ppm L-tryptophan significantly increased *Carthamus tinctorius* yield components compared to control in both seasons. In general, all amino acid types significantly increased seed yield per plant (g) and per feddan (kg), fixed oil percentage and yield per feddan (l) and petals yield per feddan (kg) compared to control. However, Reham *et al.* (2016) revealed that application of 100 ppm phenylalanine resulted in the maximum values of estimated yield of herb, leaves and oil of basil plants. Ali *et al.* (2020) demonstrated that fresh sepal's yield per roselle plant significantly increased with exogenously amino acids applied as foliar spray treatments compared to control (no spraying) treatment.

Data recorded in Table 3 show that utilizing L-tryptophan at 150 ppm + phenylalanine treatment at 150 ppm under all K rates significantly increased seed yield per plant and per feddan, fixed oil percentage and yield per feddan and petals yield per feddan of safflower plants as compared to K fertilization alone during both seasons. In the same time, the combination treatment between 72 kg K_2O/feddan and L-tryptophan + phenylalanine at 150 ppm was more effective in yield componnet values than the other treatments of K fertilization or amino acids each alone during the two seasons. In addition, According to Palizdar *et al*. (2013), using potassium fertilizer had a good impact on safflower yield and yield components. Also, Gendy and Nosir (2016) demonstrated that the higher yield components (sepals and seeds yield per plant) of roselle plant could be obtained by spraying L- tryptophan and phenylalanine acids at 100 ppm.

Table 3. Influence of potassium rate, amino acid type and their combination treatments on yield and its components of safflower plant during 2021/2022 and 2022/2023 seasons

Treatments		Seed yield/plant (g)		Seed yield/feddan (kg)		Fixed oil percentage		Fixed oil yield / feddan (l)		Petal yield /feddan (kg)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Potassium fertilizer rate (K_2O kg/feddan)											
0.0		28.49	28.80	569.83	576.00	32.07	31.10	182.96	179.64	38.52	35.68
24		31.35	32.47	627.00	649.33	32.85	31.07	206.35	202.44	40.55	42.70
48		36.13	35.04	722.50	700.83	33.68	32.71	243.77	229.91	53.67	50.28
72		37.28	36.51	745.50	730.17	34.58	35.03	258.28	256.11	54.70	53.17
LSD 5%		0.57	0.73	11.35	14.54	0.75	0.65	6.06	4.12	1.12	0.69
Amino acid type (150 ppm)											
Control		31.39	30.22	627.83	604.33	32.24	30.81	202.83	186.82	39.68	38.75
Tryptophan (Trp)		33.50	33.90	670.00	678.00	33.19	32.15	223.03	218.79	48.85	46.73
Phenylalanine (Phe)		32.28	32.70	645.50	654.00	32.59	31.95	210.97	209.70	44.97	45.30
Trp + Phe		36.08	36.00	721.50	720.00	35.15	34.99	254.52	252.78	53.93	51.05
LSD 5%		0.65	0.62	13.06	12.31	0.41	0.52	4.78	5.38	0.97	0.80
Combination influence											
0.0	Control	27.40	26.10	548.00	522.00	31.43	29.57	172.27	154.33	34.20	32.47
	Trp	27.83	29.20	556.67	584.00	32.13	31.37	178.88	183.17	39.20	35.93
	Phe	27.13	27.77	542.67	555.33	31.60	30.77	171.49	170.89	36.87	35.33
	Trp + Phe	31.60	32.13	632.00	642.67	33.10	32.70	209.20	210.15	43.80	39.00
24	Control	28.93	30.10	578.67	602.00	32.00	28.70	185.15	172.78	36.60	37.73
	Trp	31.77	33.13	635.33	662.67	32.73	29.77	207.97	197.21	42.67	43.40
	Phe	30.80	31.70	616.00	634.00	31.83	31.13	196.10	197.48	38.67	44.27
	Trp + Phe	33.90	34.93	678.00	698.67	34.83	34.67	236.17	242.29	44.27	45.40
48	Control	33.77	32.13	675.33	642.67	32.27	30.83	217.91	198.18	43.13	41.13
	Trp	36.83	35.60	736.67	712.00	33.47	32.40	246.53	230.67	57.00	53.93
	Phe	35.23	35.00	704.67	700.00	33.00	31.47	232.49	220.23	51.07	50.40
	Trp + Phe	38.67	37.43	773.33	748.67	35.97	36.13	278.13	270.55	63.47	55.93
72	Control	35.47	32.53	709.33	650.67	33.27	34.13	235.97	222.00	44.80	43.67
	Trp	37.57	37.67	751.33	753.33	34.43	35.07	258.73	264.11	56.53	53.93
	Phe	35.93	36.33	718.67	726.67	33.93	34.43	243.82	250.20	53.27	51.20
	Trp + Phe	40.13	39.50	802.67	790.00	36.70	36.47	294.59	288.14	64.20	63.87
LSD 5%		1.26	1.29	25.26	25.74	1.03	1.10	10.22	10.17	2.02	1.55

Chemical analysis

Data on both seasons in Table 4 show that, increasing potassium levels gradually increased chemical constituents (total chlorophyll content in leaves, potassium percentage in seeds and carthamin content in petals) compared with control. In addition, the maximum increase in this regard was obtained from the treatment of 72 kg K_2O/feddan compared with the other rates under study during both season. These results coincided with those found by Malik *et al.* (2016) and Khater *et al a.* (2022) on safflower. In the same time, Attia (2021) confirmed that, in comparison to control and other potassium fertilization rates, fertilizing fennel plants with 72 kg K_2O per feddan significantly increased total chlorophyll content (a + b) in leaves and potassium percentage in fruits.

Table 4. Influence of potassium rate, amino acid type and their combination treatments on some chemical constituents of safflower plant during 2021/2022 and 2022/2023 seasons

Treatments		Total chlorophyll content in leaves(SPAD)		Potassium percentage in seeds		Carthamin content in petals(mg/100g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Potassium fertilizer rate (K_2O kg/feddan)							
0.0		43.07	43.55	2.21	2.23	2.23	2.24
24		44.88	44.93	2.28	2.28	2.26	2.28
48		46.63	46.81	2.33	2.32	2.30	2.29
72		49.45	49.34	2.40	2.41	2.31	2.32
LSD 5%		0.57	0.30	0.02	0.01	0.02	0.01
Amino acid type (150 ppm)							
Control		43.53	43.68	2.22	2.23	2.22	2.24
Tryptophan (Trp)		47.07	47.13	2.32	2.32	2.29	2.30
Phenylalanine (Phe)		45.13	45.01	2.31	2.31	2.25	2.26
Trp + Phe		48.30	48.83	2.38	2.38	2.34	2.34
LSD 5%		0.51	0.45	0.01	0.01	0.01	0.01
Combination influence							
0.0	Control	42.43	43.23	2.15	2.19	2.18	2.20
	Trp	43.20	43.93	2.24	2.24	2.26	2.24
	Phe	42.70	42.43	2.20	2.22	2.18	2.21
	Trp + Phe	43.93	44.60	2.27	2.28	2.28	2.29
24	Control	43.10	42.83	2.19	2.20	2.22	2.23
	Trp	45.53	45.33	2.29	2.31	2.28	2.30
	Phe	43.83	43.70	2.30	2.27	2.24	2.25
	Trp + Phe	47.03	47.87	2.33	2.35	2.31	2.34
48	Control	43.10	43.33	2.24	2.25	2.23	2.24
	Trp	48.50	48.17	2.32	2.32	2.31	2.30
	Phe	45.97	45.87	2.32	2.34	2.29	2.27
	Trp + Phe	48.97	49.87	2.43	2.37	2.38	2.35
72	Control	45.47	45.30	2.28	2.29	2.24	2.27
	Trp	52.03	51.07	2.42	2.42	2.33	2.31
	Phe	48.03	48.03	2.41	2.41	2.29	2.35
	Trp + Phe	53.27	52.97	2.48	2.51	2.38	2.36
LSD 5%		1.05	0.84	0.03	0.02	0.03	0.02

Data described in Table 4 reveal that, 150 ppm of L-tryptophan + 150 ppm of phenylalanine acids treatment significantly increased total chlorophyll content in leaves, potassium percentage in seeds and carthamin content in petals compared to control and other types under study in the first and second seasons. Also, the highest values in this regard were achieved by mixture treatment between both amino acids in the two consecutive seasons. The advantages of increasing amino acids on enhancing chemical constituents have been previously reported by Reham *et al.* (2016) on basil plant and Radkowski and Radkowska (2018) on *Phleum pretense* plants.

The obtained data in Table 4 reveal that, was increased in total chlorophyll content in leaves, potassium percentage in seeds and carthamin content in petals as amino acids types sprayed with any K fertilization level. Moreover, chemical constituents of safflower was increased as a result of the treatment of L-tryptophan + phenylalanine each at 150 ppm combined with K fertilization rates in comparison to those K alone or those of the other ones of combination between amino acids and fertilization in both seasons. However, Ahmed and Abdelkader (2020) indicated that chemical constituents in chilli fruits were significantly increased by using 100% recommended rate of NPK fertilizers compared to control. Also, Massoud *et al.* (2020) found that foliar spaying with both tryptophan and glycine amino acids caused a pronounced increase in chemical constituents as compared to feverfew plants sprayed with control.

CONCLUSION

From above mentioned results, it is preferable to spray safflower plants with L-Tryptophan + phenylalanine each at 150 ppm and fertilize plants with high K fertilization rates (72 kg K_2O/feddan) to improve the plant growth, yield components, total chlorophyll and carthamin contents of *Carthamus tinctorius* plant.

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تحسين نمو وإنتاجية نبات القرطم باستخدام أحماض لـتريبتوفان + فينيل ألانين تحت معدلات مختلفة من السماد البوتاسي

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الملخص

اجريت تجربة حقلية بمزرعة خاصة بمدينة المنصورة بمحافظة الدقهلية بمصر خلال فصل الشتاء لعامي 2022 و2023 من أجل تحسين النمو ومكونات المحصول والمكونات الكيميائية لنباتات القرطم. وكان عاملي الدراسة في هذه التجربة هما معدل البوتاسيوم (صفر، 24، 48 و 72 كجم بو$_2$أ / فدان) ونوع الحمض الأميني (كنترول، لـ تريبتوفان، فينيل ألانين، لـ تريبتوفان + فينيل ألانين كل منها بتركيز 150 جزء في المليون) ومعاملات التداخل بينهما. أشارت النتائج المتحصل عليها أن زيادة معدلات السماد البوتاسي أدت إلى زيادة تدريجية في ارتفاع النبات وعدد الأفرع / نبات والوزن الجاف الكلي للقرطم ومحصول البذور للنبات والفدان وإنتاجية الزيت الثابت والبتلات للفدان بالإضافة إلى محتوى الكلوروفيل الكلي والمحتوى من صبغة الكارثامين. وقد تم الحصول على أعلى القيم في هذا الصدد عند تسميد النباتات بـ 72 كجم من بو$_2$أ /فدان مقارنة بالمعدلات الأخرى قيد الدراسة. بالإضافة إلى ذلك، أدى استخدام لـ تريبتوفان + فينيل ألانين بتركيز 150 جزء في المليون إلى زيادة معنوية في نمو وإنتاجية نباتات القرطم مقارنة بالكنترول (النباتات غير المرشوشة) وكل حمض أميني منفرداً. بشكل عام، تم الحصول على أفضل معاملة تداخل في تحسين إنتاجية البذور والزيوت الثابتة والكارثامين بمعاملة التداخل بين حامض التربتوفان + فينيل ألانين بمعدل 150 جزء في المليون والتسميد بـ 72 كجم من بو$_2$أ /فدان.