Role of phenylalanine as elicitor to promote some physiological and biochemical attributes of two wheat cultivars grown under sandy soil conditions

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Abstract: Phenylalanine is considered as an effective elicitor and bio-stimulant with positive influence on photosynthesis, plant growth, and yield of different crop species. So, a field experiment was carried out to investigate the role of phenylalanine at 0, 50, 75, 100 mgL^{-1} in inducing quality and quantity of two wheat cultivars. Results indicate that plant growth and yield of Gemiza 7 cultivar was more pronounced than that of Sakha 94 cultivar because of its higher significant vegetative growth parameters, total photosynthetic pigments, indole acetic acid (IAA), phenolic content, activities of both phenylalanine ammonia lyase (PAL) and tyrosine ammonia lyase (TAL)enzymes, number of grains/spike, grains weight/spike, and weight of 1000 grains. The results also revealed that100mgL^{-1} phenylalaninewas the most effective treatment followed by 75mgL^{-1} phenylalanine. It was noted that phenylalanine at 100mgL^{-1} significantly increased shoot dry weight, total photosynthetic pigments, IAA, phenolic content, PAL, TAL of both cultivars relative to corresponding controls. Likewise, 100mgL^{-1} phenylalanine significantly increased grains yield (ardabfed^{-1}) by 22.27% in Gemiza 7 cultivar and by 14.93% in Sakha 94 cultivar. On the other hand, 75mgL^{-1} phenylalanine significantly increased grains yield (ardabfed^{-1}) by 19.52% in Gemiza 7 cultivar and by 16.55% in Sakha 94 cultivar. Hence, the highest significant increase in grains yield (ardabfed^{-1}) in Gemiza 7 cultivar was recorded due to 100mgL^{-1} phenylalanine. Whereas, the highest significant increase in grains yield (ardabfed^{-1}) in Sakha 94 cultivar was recorded due to 75mgL^{-1} phenylalanine. So, suggesting using phenylalanine as abiofertilizer as an alternative to chemical fertilizers.

Key words: amino acid, biostimulant, cereals, grains quality, *sandy s*oil, *Triticum aestivum* L.

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1 Introduction

In agricultural ecosystems, a significant amount of inorganic nitrogen fertilizers is frequently applied to attain high crop productivity, which causes major environmental issues (Xu et al., 2012).Thus, organic nitrogen fertilizers, such as amino acids, peptides, and proteins, have been suggested in agricultural ecosystems to lessen the toxicity of inorganic fertilizers to the environment(Näsholm et al., 2009;Jiao et al., 2017).The application of amino acids acts as organic nitrogen polymers that may reduce the amount of inorganic fertilizer used and increase the

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productivity of crops by enhancing plant respiration, photosynthesis, water cycle activity, mineral absorption, and nutrient usage efficiency (Vernieri et al., 2005; Davies, 2010).Additionally, amino acids influence the permeability of cell membranes, which facilitates the uptake and transportation of micronutrients within plants (Marschner, 2011; Calvo et al., 2014).It is well known that amino acids are effective bio-regulators of plant growth (Pessarakli et al., 2015), and act as signal molecules to change hormone levels (Tegeder and Ward, 2012). In addition, amino acids are essential because they are widely used in the synthesis of nitrogenous non-proteinous products such vitamins, purines, pyrimidine bases, pigments, and coenzymes (Buchanan et al., 2000; Soad et al., 2010; Cao et al., 2015).Amino acids aid in the development of the root system and enhance the growth of the plant's above ground parts (Nikiforova et al., 2006) and have not negative effects on plant productivity (Näsholm et al., 2009; Franklin et al., 2017). Amino acids may be affected numerous physiological and biochemical processes, such as germination, vegetative development, flowering, and reproductive stages of plants, fruit ripening, and boosting the defense systems against abiotic and biotic stressors (Abd El-Aal et al., 2010; Teixeira et al., 2017; Khan et al., 2020).

Phenylalanine is an essential aromatic amino acid and central molecule in plant metabolism that serves as a precursor of several secondary metabolites, such as flavonoids, anthocyanins, phenyl propanoids, tannins, lignin, and salicylate, which are participated in growth of plant, reproduction and defense against both abiotic and biotic stresses (Pascual et al., 2016; Atteya et al., 2022).Interestingly, these bioactive secondary compounds have noteworthy antioxidant activity, which can be ascribed to their capability to reduce free radicals and chelate metals through the donation of hydrogen, absorption of single oxygen atoms, or chelation of reducing agents. Likewise, it has been suggested that phenylalanine regulates phenolic production, thereby enhancing the antioxidant potential of fruits (Sogvar et al., 2020). Moreover, phenylalanine is also thought to be a potent bio stimulant and elicitor that positively impacts photosynthesis, plant growth, and crop production in different of crop species (Govindaraju and Arulselvi, 2018; Samani et al., 2019; Sivaranjani et al., 2022).Although, phenylalanine is an essential aspect in plant growth and development (Pascual et al., 2016) but little attention has been paid to this aromatic amino acid.

Wheat (*Triticum aestivum* L.) is the most important cereal crop grown in the world, accounts for 26 per cent of world cereal production and plays an important role in nutritional and food security (Rahman et al., 2021; Tian et al., 2022). At least one-third of the world's population relies on wheat as its main food staple (Grote et al., 2021; Dhua et al., 2021). It considers from the most important food grain due to the grains of wheat contain a large quantity of proteins, carbohydrates, several minerals, and vitamins. Thus, efforts must be made to enhance wheat yield, in order to reduce the gap between production and consumption.

So, this investigation aimed to study the potential activity of phenylalanine application on some physiological and biochemical attributes of two wheat cultivars grown under sandy soil conditions.

2 Materials and methods

2.1 Experimental procedure

At the National Research Center's experimental station in the Nubaria area of El-Behera Governorate, Egypt, a field experiment was conducted during the winters of 2020–2021 and 2021–2022. Two cultivars of wheat (Gimeza 7 and Sakha 94) were purchased from Agricultural Research Centre Giza, Egypt. Wheat grains were sown on mid of November of both seasons in rows that were 3.5 m long and 20 cm apart. The plot area was 10.5 m^2 (3.0 m in width and 3.5 m in length). The treatments were set up as a split block design with four replicates.

According to the recommended agricultural practices of growing wheat, 60 kg grainsfed^{-1} were applied. The soil was treated with 150 kgfed^{-1} of calcium superphosphate (15.5% P_2O_5) prior to sowing.

After emergence, nitrogen was added in the form of 33.5% ammonium nitrate at a rate of 75 kgfed^{-1} in five equal doses prior to the first, second, third, fourth, and fifth irrigations. Before the first and third irrigations, two equal doses of 50 kgfed^{-1} of potassium sulphate (48.52% K_2O) were added. After 45 and 60 days from sowing, wheat plants were sprayed twice with an aqueous solution of phenylalanine at 0, 50, 75, and 100 mg L^{-1}.

2.2 Data recorded

After 75 days from sowing, wheat plant samples were collected for measuring some growth characters in terms of shoot height (cm), number of tillers/plant as well as shoot fresh and dry weight (g). Photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) in fresh leaves were determined as method recommended by Li and Chen (2015). Indole acetic acid content was extracted and determined by the method of Gusmiaty et al. (2019). Total phenolic content was determined by method described by González et al. (2003).Phenylalanine ammonia-lyase (PAL) activity in the partially purified enzyme extracts was assayed by an adaptation of the method reported by McCallum and Walker (1990). Tyrosine ammonia-lyase (TAL) activity of enzyme extracts was measured using a spectrophotometric assay of Montero et al. (1998).

At harvest, the following characters were recorded on random samples of 10 plants in each treatment: spike weight, spikelets number/spike, number of grains/spike, grains weight/spike, 1000 grains weight, grains yield, straw yield, and biological yield.

Glucose and sucrose content of the yielded grains was determined by Feteris (1965) and Handel (1968) respectively. Total soluble sugars (TSS) were estimated by the method of Mecozzi (2005). Total carbohydrates were determined calorimetrically according to the method of DuBois et al. (1956).

2.3 Statistical analysis

The average of the two seasons' worth of data was statistically investigated with analysis of variance. e Silva and de Azevedo (2016) state that the standard deviation (± SD) was used to depict the mean differences, which were computed using the least significant differences (LSD) at 5% and compared using Duncan's test.

3 Results

It was noted from Table 1 that vegetative growth parameters of Gemiza 7 cultivar (shoot height, number of tillers/plant, fresh and dry weight of shoot) were characterized by significant increases as compared to those of Sakha 94 cultivar. This result indicates the superiority of plant growth of Gemiza 7 cultivar was over than that of Sakha 94 cultivar under sandy soil conditions of Nubaria district. Moreover, application of phenylalanine at all levels caused significant increases in most of examined vegetative growth parameters by increasing phenylalanine concentration (Table 1).

Regarding the interaction between the two wheat cultivars and phenylalanine application, it is noted that all applied treatments caused marked increases in vegetative growth parameters of both wheat cultivars relative to corresponding controls (Table 1). Application of phenylalanine at 100mgL^{-1} was the most effective treatment. Since, it significantly increased shoot dry weight of Gemiza 7 cultivar from 1.12 to 1.74g (55.36%) and that of Sakha 94 cultivar from 0.97 to 1.34 (38.14%) relative to corresponding controls. These results indicate that growth of Gemiza 7 cultivar under sandy soil conditions and also its response to phenylalanine treatments was more pronounced than growth of Sakha 94 cultivar under the same conditions.

Regarding the contents of photosynthetic pigments of fresh leaf tissues of both wheat cultivars under investigation (Table 2), the collected results indicate that fresh leaf tissues of Gemiza 7 cultivar was characterized by higher significant values of chlorophyll a and total photosynthetic pigments whereas fresh leaf tissues of Sakha 94 cultivar showed higher significant values of chlorophyll b and carotenoids. Moreover, all applied phenylalanine treatments significantly increased all components of photosynthetic pigments and these values were increased by increasing phenylalanine concentrations (Table 2).

Table 1 Impact of phenylalanine application on vegetative growth parameters of two wheat cultivars grown under sandy soil conditions

Treatments		Shoot height(cm)	Number of tillers/plant	Fresh weight of shoot(g)	Dry weight of shoot (g)
Effect of cultivars					
Gemiza 7		65.33 a	4.41 a	4.99 a	1.39 a
Sakha 94		60.42 b	4.16 b	4.07 b	1.15 b
LSD at 5%		2.35	0.20		0.12
Effect of phenylalanine levels					
Phenylalanine (mgL^{-1})	0	57.83 c	3.66 b	4.13 b	1.05 c
	50	60.33 b	4.33 ab	4.56 a	1.13 c
	75	66.16 a	4.50 a	4.73 a	1.38 b
	100	67.16 a	4.66 a	4.69 a	1.54 a
LSD at 5%		1.64	0.74	0.19	0.15
Effect of interaction between cultivars and phenylalanine levels					
Gemiza 7					
Phenylalanine (mgL^{-1})	0	62.66±0.10 d	3.66 ±0.33 b	4.49±0.07 b	1.12±0.05 cde
	50	64.66±0.11 cd	4.33±0.33 ab	5.04±0.09 a	1.17±0.06 cde
	75	68.00±0.01 ab	4.66 ±0.33 ab	5.23±0.05 a	1.53±0.09 ab
	100	66.00±0.02 bc	5.00±0.00 a	5.19±0.03 a	1.74±0.08 a
Sakha 94					
Phenylalanine (mgL^{-1})	0	53.00±0.01 f	3.66±0.33 b	3.77±0.05 d	0.97±0.03 e
	50	56.00±0.15 e	4.33±0.33 ab	4.08±0.07 c	1.08±0.01 de
	75	64.33± 0.4cd	4.66±0.33 ab	4.24±0.06 bc	1.23±0.03 cd
	100	68.33±0.011 a	4.00±0.00 ab	4.19±0.09 c	1.34±0.02 bc
LSD at 5%		2.32	1.05	0.27	0.22

Note: Means followed by the same letter for each tested parameter are not significantly different by Duncan's test ($p \leq 0.05$) and presented by± SD

Table 2 Impact of phenylalanine application on photosynthetic pigments of two wheat cultivars grown under sandy soil conditions

Treatments		Chlorophyll a	Chlorophyll b	Chlorophyll a+ Chlorophyll b	Carotenoids	Total photosynthetic pigments
		(mg/g Fresh weight)				
Effect of cultivars						
Gemiza 7		22.61 a	8.16 b	30.77 a	3.52 b	34.29 a
Sakha 94		20.07 b	8.57 a	28.65 b	4.12 a	32.77 b
LSD at 5%		0.32	0.04	0.35	0.11	0.46
Effect of phenylalanine levels						
Phenylalanine (mgL^{-1})	0	18.42 c	7.31 c	25.72 c	3.44 d	29.16 c
	50	21.25 b	8.83 b	29.63 b	3.79 b	33.42 b
	75	21.20 b	8.73 ab	33.57 a	3.61 c	33.55 b
	100	24.51 a	9.05 a	29.94 b	4.44 a	38.01 a
LSD at 5%		0.17	0.58	0.73	0.09	0.75
Effect of interaction between cultivars and phenylalanine levels						
Gemiza 7						
Phenylalanine (mgL^{-1})	0	19.50±0.08 e	6.90±0.03 d	26.41±0.12 e	3.29±0.02 d	29.71±0.09 e
	50	22.97±0.10 b	7.84±0.33 c	30.81±0.44 c	3.59±0.01 c	34.40±0.46 c
	75	21.72±0.03 c	9.18±0.01 a	30.90±0.02 c	3.19±0.01 d	34.09±0.03 c
	100	26.27±0.12 a	8.70±0.07 ab	34.98±0.19 a	4.02±0.01 b	39.00±0.18 a
Sakha 94						
Phenylalanine (mgL^{-1})	0	17.33±0.05 f	7.71±0.06 cd	25.03±0.11 f	3.59±0.01 c	28.62±0.09 f
	50	19.53±0.02 e	8.92±0.29 ab	28.45±0.26 d	3.99±0.01 b	32.44±0.27 d
	75	20.69±0.02 d	8.29±0.07 bc	28.98±0.09 d	4.02±0.05 b	33.01±0.14 d
	100	22.72±0.08 b	9.40±0.18 a	32.15±0.10 b	4.86±0.05 a	37.01±0.05 b
LSD at 5%		0.24	0.82	1.04	0.12	1.06

Note: Means followed by the same letter for each tested parameter are not significantly different by Duncan's test ($p \leq 0.05$) and presented by± SD

Regarding the interaction between two wheat cultivars and phenylalanine application, it is noted that all applied treatments caused significant increases in all components of photosynthetic pigments of both wheat cultivars relative to corresponding controls (Table 2). Application of phenylalanine at 100mgL^{-1} was the most effective treatment followed by phenylalanine at 75mgL^{-1}. Since, phenylalanine at 100mgL^{-1} significantly increased total photosynthetic pigments of Gemiza 7 cultivar from 29.71 to 39.00 mgg^{-1} (31.27%) and that of Sakha 94 cultivar from 28.62 to 37.01 mgg^{-1} (29.31%) relative to corresponding controls.

Further, fresh leaf tissues of Gemiza 7 cultivar was characterized by higher significant values of some chemical composition in terms of IAA, phenolic content, activities of both PAL and TAL enzymes as compared to those of Sakha 94 cultivar (Table 3).Moreover, all applied phenylalanine treatments significantly increased values of IAA, phenolic content, activities of both PAL and TAL enzymes by increasing phenylalanine concentrations (Table 3).

Regarding the interaction between two wheat cultivars and phenylalanine application, it was noted that all applied treatments caused significant increases in values of IAA, phenolic content, activities of both PAL and TAL enzymes of both wheat cultivars under investigation relative to corresponding controls (Table 3). Application of phenylalanine at 100mgL^{-1} was the most effective treatment followed by phenylalanine at 75mgL^{-1}. Since, phenylalanine at 100mgL^{-1} significantly increased IAAby 64.19% and 68.65 %, phenolic content by 66.73% and 91.13%, PAL by 30.96% and 23.36%, TAL by 33.84% and 50.37% in Gemiza 7 cultivar and Sakha 94 cultivar respectively relative to corresponding controls.

Table 3 Impact of phenylalanine application on indole acetic acid, phenolic content, and activities of phenylalanine ammonia lyase and tyrosine ammonia lyase of fresh leaf tissues of two wheat cultivars grown under sandy soil conditions

Treatments		Indole acetic acid (μg g^{-1})	Phenolic content (mgg^{-1})	PAL	TAL
		Effect of cultivars			
Gemiza 7		58.30 a	34.27 a	7.78 a	3.84 a
Sakha 94		50.21 b	32.15 a	6.97 b	3.51 b
LSD at 5%		0.76	4.36	0.01	0.07
		Effect of phenylalanine levels			
Phenylalanine (mgL^{-1})	0	39.85 d	23.67 c	6.28 d	2.98 d
	50	52.66 c	32.02 b	7.06 c	3.40 c
	75	58.18 b	34.79 b	8.15 a	4.11 b
	100	66.33 a	42.38 a	8.01 b	4.21 a
LSD at 5%		1.02	4.36	0.09	0.07
		Effect of interaction between cultivars and phenylalanine levels			
		Gemiza 7			
Phenylalanine (mgL^{-1})	0	42.98±0.15 f	23.90±0.14 d	6.62±0.05 e	3.28±0.02 e
	50	57.10±0.43 c	30.98±0.30 cd	7.73±0.06 c	3.63±0.07 d
	75	62.62±0.26 b	36.53±0.06 bc	8.11±0.01 b	4.05±0.01 c
	100	70.57±0.55 a	45.68±0.40 a	8.67±0.03 a	4.39±0.02 a
		Sakha 94			
Phenylalanine (mgL^{-1})	0	36.81±0.11 g	23.44±0.55 d	5.95±0.06 g	2.68±0.01 g
	50	48.22±0.31 e	33.06±0.25 bc	6.40±0.03 f	3.17±0.01 f
	75	53.75±0.12 d	33.03±0.24 bc	8.18±0.01 b	4.17±0.02 b
	100	62.08±0.44 b	39.08±0.55 ab	7.34±0.01 d	4.03±0.01 c
LSD at 5%		1.44	8.01	0.12	0.10

Note: Means followed by the same letter for each tested parameter are not significantly different by Duncan's test ($p \leq 0.05$) and presented by± SD

Regarding wheat yield and its components, it was noted from Table 4 that yield components of Gemiza 7 cultivar showed significant increases as compared to Sakha 94 cultivar in terms of number of grains/spike, grains weight/spike, and weight of 1000 grains. Whereas, a nonsignificant increase appeared between two cultivars in terms of grains yield (ardabfed^{-1}), straw yield (tonfed^{-1}) and biological yield (tonfed^{-1}).Since, increasing wheat granis yield is the main target, it was noted that application of phenylalanine at all concentrations significantly increased number of grains/spike, grains weight/spike, and weight of 1000 grains yield (ardabfed^{-1}), straw yield (tonfed^{-1}) and biological yield (tonfed^{-1}) (Table 4). Whereas, number of spikelets /spike showeda significant increases due to 100mgL^{-1}phenylalanine. The enhancement effect of phenylalanine treatments was increased by increasing its concentrations.

Regarding the interaction between two wheat cultivars and phenylalanine application, it was noted that all applied treatments caused significant increases in values of grains yield and yield attributes of both wheat cultivars under investigation (Table 4). Application of 100mgL^{-1} phenylalanine was the most effective treatment followed by 75mgL^{-1} phenylalanine. Since, 100mgL^{-1} phenylalanine significantly increased grains yield (ardabfed^{-1}) from 11.58 to 14.16 (22.27%) in Gemiza 7 cultivar and from 12.14 to 13.95 (14.93%) in Sakha 94 cultivar. In addition, 75mgL^{-1} phenylalanine significantly increased grains yield (ardabfed^{-1}) from 11.58 to 13.84 (19.52%) in Gemiza 7 cultivar and from 12.14 to 14.15 (16.55%) in Sakha 94 cultivar. Hence, the highest significant increase in grains yield (ardabfed^{-1}) in Gemiza 7 cultivar was recorded due to 100mgL^{-1} phenylalanine. Whereas, the highest significant increase in grains yield (ardabfed^{-1}) in Sakha 94 cultivar was recorded due to 75mgL^{-1} phenylalanine.

Table 4 Impact of phenylalanine application on grains yield and its components of two wheat cultivars grown under sandy soil conditions

Treatments		Spike weight (g)	Number of spikeletes /spike	Number of grains/spike	Weight of grains/spike (g)	Weight of 1000 grains(g)	Grains yield(Ardabe/fed)	Straw yield(ton/fed)	Biological yield(ton/fed)
Effect of cultivars									
Gemiza 7		2.20 a	19.50 a	47.33 a	1.84 a	39.54 a	13.00 a	2.23 a	4.31 a
Sakha 94		2.06 a	20.50 a	41.03 b	1.65 b	35.45 b	13.43 a	2.29 a	4.24 a
LSD at 5%		0.19	1.24	3.88	0.11	0.56	0.26	0.10	0.60
Effect of phenylalanine levels									
Phenylalanine (mgL^{-1})	0	1.83 c	18.50 b	38.66 b	1.43 c	33.27 c	11.86 c	2.11 c	3.69 d
	50	2.16 b	20.16 ab	45.00 a	1.80 b	37.58 b	12.96 b	2.26 b	4.23 c
	75	2.18 b	20.00 ab	46.16 a	1.78 b	39.56 a	14.00 a	2.32 ab	4.58 b
	100	2.34 a	21.30 a	47.00 a	1.95 a	39.57 a	14.05 a	2.36 a	4.84 a
LSD at 5%		0.11	2.21	3.26	0.09	0.37	0.35	0.07	0.19
Effect of interaction between cultivars and phenylalanine levels									
Gemiza 7									
Phenylalanine (mgL^{-1})	0	1.88±0.01 ef	17.66±0.88 b	40.66±0.66 bc	1.56±0.04 d	34.19±0.37 de	11.58±0.31 d	2.10±0.02 d	3.82±0.02 c
	50	2.19±0.07 bcd	19.66±0.66 ab	49.33±0.33 a	1.77±0.04 c	40.18±0.34 abc	12.43±0.26 c	2.24±0.04 c	4.27±0.06 b
	75	2.33±0.06 ab	19.33±0.66 ab	49.33±1.02 a	1.96±0.05 ab	41.69±0.71 ab	13.84±0.15 ab	2.24±0.05 c	4.80±0.28 a
	100	2.40±0.11 a	21.33±0.88 a	50.00±1.10 a	2.06±0.05 a	42.11±0.56 a	14.16±0.27 a	2.35±0.01 ab	4.90±0.13 a
Sakha 94									
Phenylalanine (mgL^{-1})	0	1.77±0.08 f	19.33±0.33 ab	36.66±1.05 c	1.30±0.02 e	32.35 ±0.56 e	12.14±0.39 c	2.12±0.03 d	3.56±0.06 c
	50	2.13±0.09 cd	20.66±0.33 ab	40.66±0.33 bc	1.84±0.08 c	34.98±0.33 de	13.49±0.36 ab	2.28±0.05 bc	4.19±0.02 b
	75	2.04±0.01 de	20.66±0.66 ab	43.00±1.0 b	1.60±0.01 d	37.43±0.37 bcd	14.15±0.12 a	2.39±0.01 a	4.36±0.11 b
	100	2.28±0.08 abc	21.33±0.88 a	44.00±1.00 b	1.85±0.02 bc	37.03±0.49 cd	13.95±0.15 ab	2.36±0.04 ab	4.78±0.05 a
LSD at 5%		0.16	3.12	4.62±	0.12	4.62	0.50	0.11	0.27

Note: Means followed by the same letter for each tested parameter are not significantly different by Duncan's test ($p\leq 0.05$) and presented by± SD

Regarding to some chemical composition of the yielded grains of the two wheat cultivars under investigation, it was noted that grains of Gemiza 7 cultivar was characterized by higher glucose content than those of Sakha 94 cultivar. Whereas, grains of Sakha 94 cultivar was characterized by significant increase of both sucrose and total soluble sugars and nonsignificant increase in total carbohydrate content than those of Gemiza 7 cultivar (Table 5). Phenylalanine treatments at all concentrations significantly increased glucose, sucrose, total soluble sugars and total carbohydrate content relative to control treatment. The most effective treatment was 100mgL^{-1} phenylalanine followed by 75mgL^{-1} phenylalanine (Table 5).

Regarding interaction between two wheat cultivars and phenylalanine application at 50, 75 and 100 mgL^{-1}, it was noted that all applied treatments caused significant increases in values of glucose, sucrose, total soluble sugars and total carbohydrate content of both cultivars relative to corresponding controls (Table 5). phenylalanine application at 75 mgL^{-1} significantly increased total carbohydrate content from 43.66% to 46.56% (6.64%) in Gemiza 7 cultivar and from 44.76% 46.35%(3.55%) in Sakha 94 cultivar relative to corresponding controls. Whereas, phenylalanine application at 100 mgL^{-1} significantly increased total carbohydrate content from 43.66% to 46.03% (5.43%) in Gemiza 7 cultivar and from 44.76% 46.54%(3.97%) in Sakha 94 cultivar relative to corresponding controls. Clearly, the recorded results indicate the significant increases of total carbohydrate content in Gemiza 7 cultivar due to phenylalanine application at 75 mgL^{-1} and 100 mg L^{-1} was higher than that of Sakha 94 cultivar.

Table 5 Impact of phenylalanine application on some chemical composition of the yielded grains of two wheat cultivars grown under sandy soil conditions

Treatments		Glucose (%)	Sucrose (%)	Total soluble sugars (%)	Total carbohydrate (%)
Effect of cultivars					
Gemiza 7		0.52 a	14.75 b	18.39 b	45.50 a
Sakha 94		0.48 a	15.76 a	19.18 a	45.88 a
LSD at 5%		0.03	0.08	0.12	0.73
Effect of phenylalanine levels					
Phenylalanine	0	0.45 c	12.29 d	18.47 c	44.21 c
(mgL^{-1})	50	0.50 b	15.76 c	18.65 b	45.83 b
	75	0.53 a	16.63 a	19.24 a	46.45 a
	100	0.50 b	16.36 b	18.47 b	46.29 a
LSD at 5%		0.02	0.21	0.15	0.26
Effect of interaction between cultivars and phenylalanine levels					
Gemiza 7					
Phenylalanine	0	0.47±0.0 d	11.38±0.02 f	17.75±0.05 f	43.66±0.01 e
(mgL^{-1})	50	0.51± 0.0 bc	15.53±0.06 d	18.23±0.012 e	45.76±0.05 c
	75	0.56±0.01 a	16.55±0.06 b	18.88±0.13 cd	46.56±0.06 a
	100	0.52±0.0 b	15.55±0.11 d	18.69±0.11 d	46.03±0.02 bc
Sakha 94					
Phenylalanine	0	0.44±0.0 e	13.19±0.02 e	19.20±0.26 b	44.76±0.04 d
(mgL^{-1})	50	0.48±0.0 d	15.98±0.08 c	19.06±0.08 bc	45.89±0.06 c
	75	0.51±0.0 bc	16.71±0.03 b	19.60±0.04 a	46.35±0.29 ab
	100	0.49±0.0 cd	17.17±0.08 a	18.85±0.09 cd	46.54±0.17 a
LSD at 5%		0.02	0.29	0.22	0.36

Note: Means followed by the same letter for each tested parameter are not significantly different by Duncan's test ($p\leq 0.05$) and presented by± SD

4 Discussion

First of all, exogenous application of amino acids provide an immediate nutritional source (nitrogen and carbon) for plant cells that are absorbed through the stomata and cell membrane and transported to the meristems a few hours after absorption (Cao et al., 2015) at a faster rate than inorganic nitrogen (Thom et al. 1981;Tantawy et al., 2009; Salmani and Rezaei,2023). Amino acids as organic acids enter the Krebs cycle, break down and produce energy during respiration, and have a direct effect on yield (Abdel Aziz et al., 2010; Khan et al., 2020) through their influence on the process of nitrogen uptake and assimilation (Halpern et al., 2015; Salmani and Rezaei, 2023). Amino acids not only act as bio stimulants but also as precursors to phytohormones (Calvo et al., 2014; Cao et al., 2015), signaling molecules for various physiological processes such as regulators of nitrogen uptake (Halpern et al., 2015), root development (Cao et al.,2015), and production of antioxidants (Abd El-Aal et al., 2010).The application of amino acids improves growth and photosynthesis by increasing leaf area and chlorophyll content, as well as fruit set and fruit weight of cabbage under drought stress (Haghighi et al., 2020).

The achievement of phenylalanine on growth parameters as shown in Table 1 may be due to the its role as organic biofertilizer that providing the necessary nutrient (organic nitrogen) to plants (Al-Sayed et al., 2020; Al-Mohammad et al., 2021). This macro-element is one of crucial substances for the growth and development of plants, which has an impact on numerous enzymes that regulate physiological processes in plants (Khalid, 2012).In addition, positive impact of phenylalanine on growth parameters can be explained by activating gibberellic acid biosynthesis (Al-Duraid et al., 2019) which stimulate the rate of growth (cell elongation, cell division, and differentiation) and consequently increasing area of leaf, plant fresh and dry weight (Taiz and Zeiger, 2002), and amount of chlorophyll (Gendy and Nosir, 2016) as well as stimulated the flowering process and decrease flowers abortion and finally lead to increase yield and its components(Al-Duraid et al., 2019). Similarly, all of the physiological and biochemical aspects as well as the floral characteristics of gerberas (total carbohydrates in leaves, number of inflorescences, diameter of inflorescence, length of inflorescence stalk, and total carotenoids content in inflorescence) were found to be positively impacted by foliar spraying with phenylalanine at 150 mgL^{-1}, as mentioned by Mahdi and Saeed (2019). Moreover, Abaka et al. (2023) mentioned that spraying of phenylalanine at a concentration of 50 mgL^{-1}on black rice was significantly improved vegetative growth parameters, yield, its components and active compounds. Additional explanation by Sadak et al. (2023)who concluded that using phenylalanine as foliar treatment improved growth indices, photosynthetic pigments, IAA, phenolic content, and yield of peanut plants under sandy soil. Furthermore, the role of amino acid application in increases photosynthetic pigments may be attributed to the function of amino acid in initiating the metabolic role leading to chlorophyll production and the succinyl COA (Kerb's cycle intermediate) (Taylor et al., 1982). Likewise, foliar application phenylalanine was found to produce positive effect on plant physiological parameters by enhancing the activity of chlorophyll synthesizing enzymes (Samani et al., 2019).

Moreover, L-phenylalanine was used to improve formation of secondary metabolites such as phenolics and flavonoids in plant cell (Koca and Karaman, 2015). L-phenylalanine is substrate of phenylalanine ammonia lyase (PAL) which catalyzes L-phenylalanine into Trans-cinnamic acid as the first step of the biosynthesis of different phenolic compounds (Kubota et al., 2001). PAL and tyrosine ammonia-lyase (TAL) are regulatory enzymes involved in the phenylpropanoid pathway (Vogt, 2010). According to Feduraev et al. (2020), adding phenylalanine can improve PAL and TAL activity. So, phenylalanine is a vital stimulant and modulates of the phenylpropanoide path leading to the formation of phenolic compounds (Al-Duraid et al., 2019).

Earlier, the amino acid caused activation of photosynthesis especially when sprayed on plant as a nutrient solution, which leads to an increase in production of carbohydrates (Köksal et al., 1999). Awad et al. (2007) showed that spray with phenylalanine increased in the percentage of carbohydrates due to the fact that amino acids are precursor of natural products, including carbohydrates, plant pigments, alkaloids and hormones (Maeda and Dudareva, 2012).

The increase in yield parameters of two wheat cultivars due to phenylalanine treatments as shown in Table 4 may be due to the increase of photosynthtic pigments (Table 2) and accumulation of dry matter as a result of the increase in vegetative growth indicators (Table 1), which provided an effective exposure area to light with high chlorophyll concentrations, and increased transfer of photo-assimilates from leaves to grains thus increased their weights which resulted in increased different yield components as well as improving the nutritional value of the yielded wheat grains(Table 5). Moreover, these increases could be due to increased endogenous growth regulators (IAA) as shown in Table 3.

5 Conclusion

It could be concluded that plant growth of Gemiza 7 cultivar under sandy soil conditions of Nubaria district was more pronounced than plant growth of Sakha 94 cultivar. Moreover, application of phenylalanine at 100mgL^{-1} significantly increased grains yield (ardabfed^{-1}) by 22.27% in Gemiza 7 cultivar and by 14.93% in Sakha 94 cultivar. On the other hand, 75mgL^{-1} phenylalanine significantly increased grains yield (ardabfed^{-1}) by 19.52% in Gemiza 7 cultivar and by 16.55% in Sakha 94 cultivar. Hence, the highest significant increase in grains yield (ardabfed^{-1}) in Gemiza 7 cultivar was recorded due to 100mgL^{-1} phenylalanine. Whereas, the highest significant increase in grains yield (ardabfed^{-1}) in Sakha 94 cultivar was recorded due to 75mgL^{-1} phenylalanine.

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