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Effect of *Arbuscular Mycorrhiza* and Glutamic Acid on Growth, Yield, Some Chemical Composition and Nutritional Quality of Wheat Plant Grown in Newly Reclaimed Sandy Soil.

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ABSTRACT

A field experiment was carried out at the Agricultural Production and Research Station, National Research Centre (NRC), Nubaria Province, Egypt during two successive winter seasons 2011/2012 and 2012/2013.Inorder to study the effects of different concentrations of glutamic acid in absence and presence of arbuscular mycorrhiza (AM) on some morphological criteria, some biochemical parameters and grain yield quantity and quality of wheat plant. In general, all growth parameters increased by 50&100 mg/l glutamic acid treatments (plant height, tiller fresh and dry weight, root fresh and dry weight) , and yield components concomitantly with an increase in the levels of IAA, photosynthetic pigments, total soluble sugar, total carbohydrates and yield components. Moreover, glutamic acid concentrations caused marked increases in nutritional values of the yielded grains, carbohydrates %, proteins %, macronutrient, micronutrients, total flavonoids, antioxidant activity, total amino acids and essential amino acids in yielded grain. Addition of AM to soil generally caused significant increases in the studied parameters of wheat plant. The interaction between glutamic acid and AM was more effective as it gave higher increases in the studied parameters compared with glutamic acid treatments. As a conclusion, cultivation of wheat plant in the presence of mycorrhiza with 100 mg/l glutamic acid improved the nutritional values of the yielded grains.

Keywords: *Arbuscular mycorrhiza,* Glutamic acids, nutritional values, Wheat, Yield

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the third most- produced cereal in the world after maize and rice, but in terms of dietary intake, it is currently second to rice as the main food crop, while in Egypt it is considered the strategic food crop. As a hardy crop, this can grow in a wide range of environmental conditions and that permits large-scale cultivation as well as long-term storage of food. Currently, around 70 % of this crop is used for food, 19 % for animal feed and the remaining 11% is used in industrial applications, including biofuels. The importance of wheat is mainly due to the fact that its seed can be ground into flour, semolina, etc., which form the basic ingredients of bread and other bakery products, as well as pastas, and thus it presents the main source of nutrients to the most of the world population. The nutritional value of wheat is extremely important as it takes an important place among the few crop species being extensively grown as staple food sources. Moreover**,** Yu, *et al.,* (2002) suggesting that wheat may serve as an excellent dietary source of natural antioxidants for disease prevention and health promotion.

Egypt suffers from food shortage problem as a result for a huge increment of population and the huge loss of agricultural soils due to desertification and erosion problems. Therefore, it is very essential to increase wheat productivity. Extending wheat growing outside the Nile Valley is the first effort toward overcoming wheat problems. The experiments will be carried at the new reclaimed sandy and salty soils in Egypt. This region, as a part of the Sahara Desert of Northern Africa, is exposed to a combination of environmental stress conditions including low water availability, high irradiances, temperature fluctuations, soil salinity and nutrients deprivation. A possible approach to increase crop productivity is the application of arbuscular mycorrhiza (AM) and foliar application with amino acids as glutamic acid. As well as the intrinsic adaptation mechanisms developed by plants, under natural conditions they grow in association with a number of soil microorganisms. Some of these microorganisms, especially bacteria and fungi, can improve plant performance when environmental conditions are adverse (Aroca and Ruı´z-Lozano, 2009**).** Arbuscular mycorrhiza fungi establish a symbiotic association with the roots of 80% of terrestrial plants **(**Smith and Read, 2008). This AM symbiosis can be defined as a specialized system for nutrient uptake and transfer that is more efficient than roots alone. However, the uptake and transfer of nutrients to the host plant is not the only physiological role of AM symbiosis. Indeed, in most cases studied, the association between an AM fungus and a plant makes the host plant more tolerant to abiotic stresses **(**Dodd and Ruı´z-Lozano, 2012**)**. Arbuscular mycorrhiza fungi are important in sustainable agriculture because they improve plant water relations and thus increase the drought resistance of host plants, they improve disease resistance and they increase mineral uptake by increased acquisition of phosphorus and other low mobile mineral nutrients, which reduce the use of fertilizers. They can also break down certain complex minerals and organic substances in the soil and make it available to their hosts **(**Mona, 2001; Soliman et al., 2012).

Amino acids are organic nitrogenous compounds are and building blocks in the synthesis of proteins which formed by a process in which ribosome catalyze the polymerization of amino acids (*Davies,* 1982). They are known as growth factors of higher plants and they stated them as constituents of the protein part enzyme **(**Levitt, 1980). The role of amino acid in stimulating growth and some chemical constituents of several plant species were studied by Talaat *et al.*, (2005) on *Catharanthus roseus* L., Abd El-Aziz *et al.,* (2010) on Thuja orientalis and Sadak *et al.,* (2012) on *Helianthus annuus* L.

So, the target of our work was to study the effect AM fungi and/or glutamic acid on growth, some physiological and chemical parameters and yield quantity & quality of wheat grown in newly reclaimed sandy soil conditions. Moreover, the most important wheat grain components and their nutritional value of wheat are also discussed.

MATERIALS AND METHODS

A field experiment was carried out at the experimental Station of National Research Centre, Nubaria district El-Behrea Governorate–Egypt, during two successive winter seasons of 2011/2012 and 2012/2013. The soil of both experimental sites was Newly Reclaimed sandy soil where mechanical and chemical analysis is reported in) Table 1) according to Chapman and Pratt (1978).

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Table 1: Mechanical, chemical and nutritional analysis of the experimental soil.

Mechanical analysis:

Sand		Silt 20-0µ%	Clay < 2µ%	Soil texture
Course 2000-200µ%	Fine 200-20µ %			
47.46	36.19	12.86	4.28	Sandy

Chemical analysis:

pH 1:2.5	EC dSm^{-1}	$CaCo_3$	OM%	Soluble Cations meq/l				Soluble anions meq/l			
				Na^+	K^+	Mg^+	Ca^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
7.60	0.13	5.3	0.06	0.57	0.13	0.92	1.0	0.0	1.25	0.48	0.89

Nutritional analysis:

Available nutrients						
Macro element ppm		Micro element ppm				
N	P	K	Zn	Fe	Mn	Cu
52	12.0	75	0.14	1.4	0.3	0.00

The aim of this work was to investigate effect of AM fungi addition to the soil with one level (1Kg/fed) and/or foliar treatment with glutamic acid with 50 and 100 mg/l concentration on wheat plant grown in newly reclaimed sandy soil. Seeds of wheat (Gimeza 10 cultivar) cultivar were obtained from Agricultural Research Centre Giza, Egypt grown under newly reclaimed sandy soils.

The experimental design was split plot design with four replication, which AM occupy the main plots and glutamic concentrations were allocated at random in sub-plots. Wheat (*Triticum aestivum* L.) grains were sown on the 15th November in both season in rows 3.5 meters long, and the distance between rows was 20cm apart, Plot area was 10.5 m^2 (3.0 m in width and 3.5 m in Length). The recommended agricultural practices of growing wheat seed were applied and the seeding rate was (60 Kg grains/Fed). Pre-sowing, 150 kg/fed. of calcium super-phosphate (15.5 % P_2O_5) was applied to the soil. Nitrogen was applied after emergence in the form of ammonium nitrate 33.5% at rate of 75 Kg/fed was applied at five equal doses before the 1st, 2nd ,3rd, 4th and 5thirrigation. Potassium sulfate (48.52 % K2O) was added at two equal doses of 50 kg/fed, before the 1st and 3rdirrigations. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days. Soil was amended with AM. In both seasons, foliar application of glutamic acid (0, 50 and 100 mg/l) was carried out twice; where plants were sprayed after 45 and 60days from sowing. Plant samples were taken after 75 days from sowing for measurements growth characters were measured in terms of, plant height (cm), fresh and dry weight g/plant, root fresh and dry weight (g). Plant samples were taken for chemical analysis after 75 days from sowing for chemical analysis of photosynthetic pigments, total soluble sugars, polysaccharides, total carbohydrates, total IAA, total phenol content. At harvest the following characters were recorded on random samples of 10 girded plants in each plot to estimate the following characters: Plant height (cm), spikelet no/spike, 1000 grains weight (g), grains yield / spike (g), Straw yield, Biological yield (ton/fed) and Grain yield (Ardbe/fed). Some chemical parameters are measured in the yielded grains as proteins %, carbohydrates %, some macro & micro elements, flavonoids, antioxidant activity and amino acids content.

Chemical analysis:

Photosynthetic pigments: Total chlorophyll a and b and carotenoids contents in fresh leaves were estimated using the method of Lichtenthaler and Buschmann (2001). Total soluble sugars (TSS), were extracted by the method of (Homme *et al.,* 1992). TSS was analyzed by (Yemm and Willis, 1954). Determination of total carbohydrates was carried out according to Herbert *et al.*, (1971). Indole acetic acid content were extracted and analyzed by the method of Larsen *et al.,* (1962). Total phenol content, the extract was extracted as IAA extraction, and then measured as described by Danil and George (1972). Total protein concentration of the supernatant was determined according to the method described by Bradford (1976). Total N was determined by using micro-Kjeldahl method as described in AOAC (1970). Macro and microelement contents of the yielded grains were determined according to *Chapmen* and *Pratt* (1978). Phosphorus was determined using a Spekol spectrocolorimeter (VEB Carl Zeiss; Jena, Germany, while,

estimation of K+ contents were done using a flame photometer. Fe2+, Mn2+, Zn2+ contents were estimated using atomic absorption spectrophotometer. Total flavonoids were determined using the method reported by Chang *et al.,* (2002). The antioxidant activity (DPPH radical scavenging) was determined using the method of Liyana-Pathiranan and Shahidi (2005). Amino acid contents identification and determination of the amino acid composition of the wheat grain was carried out by using HPLC (Eppdrof, Germany).

Statistical analysis:

The data were statistically analyzed on complete randomized design system according to Snedecor and Cochran (1980). Combined analysis of the two growing seasons was carried out. Means were compared by using least significant difference (LSD) at 5% levels of probability.

RESULTS

Changes in growth criteria:

Data in (Table 2) shows the effect of different concentrations of glutamic acid(50 and 100 mg/l) on growth criteria of wheat plants cultivated in newly reclaimed sandy soil amended with AM. Data clearly show that, addition of AM fungi increased significantly the studied growth criteria (plant height, tiller fresh and dry weight, root fresh and dry weight) compared with control plants. Data also, show that foliar treatment with glutamic acid caused progressive significant increases in all the above mentioned growth criteria for the plants cultivated in the absence and presence of AM fungi. The maximum increases in all the growth criteria were obtained by using 100 mg/l glutamic acid in absence and presence of AM fungi.

Table 2: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on morphological criteria of wheat plant under newly reclaimed sandy soil (mean of two season) (75 days from sowing). Each value represents the mean ± standard error (n =5).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Treatment		Plant height (cm)	Tiller fresh wt. (g)	Tiller dry wt. (g)	Root fresh wt. (g)	Root dry wt. (g)
AM	Glu					
-	0	41.00±0.40	6.97±0.26	1.57±0.13	1.33±0.03	0.65±0.03
	50 mg/l	47.33±0.33	9.03±0.15	1.93±0.13	1.57±0.08	0.70±0.04
	100 mg/l	48.67±0.22	9.73±0.14	2.03±0.12	2.00±0.11	0.96±0.06
+	0	50.33±0.57	10.23±0.14	2.01±0.06	2.17±0.09	1.21±0.08
	50 mg/l	53.00±0.50	10.83±0.29	2.44±0.09	2.47±0.12	1.81±0.15
	100 mg/l	54.33±0.29	12.30±0.15	2.80±0.09	2.93±0.16	1.94±0.16
LSD at 5%		2.15	1.16	0.33	0.18	0.11

Photosynthetic pigments contents:

Data in Figure (1) show the response of photosynthetic pigment of wheat leaves sprayed with different concentrations of glutamic acid cultivated in soils amended with AM. The results showed that growing plants in the presence of AM fungi led to an increase in photosynthetic pigments when compared to plants grown in the absence of AM. Results also reveal that, significant increases in all photosynthetic pigment contents in response to treatment with different concentrations of glutamic acid in the presence or absence of AM. Increasing glutamic acid concentrations increased gradually photosynthetic pigments constituents in absence and presence of AM. Plants treated with 100 ppm glutamic amended with AM had the highest total chlorophyll content by 37% as compared with the untreated plant.

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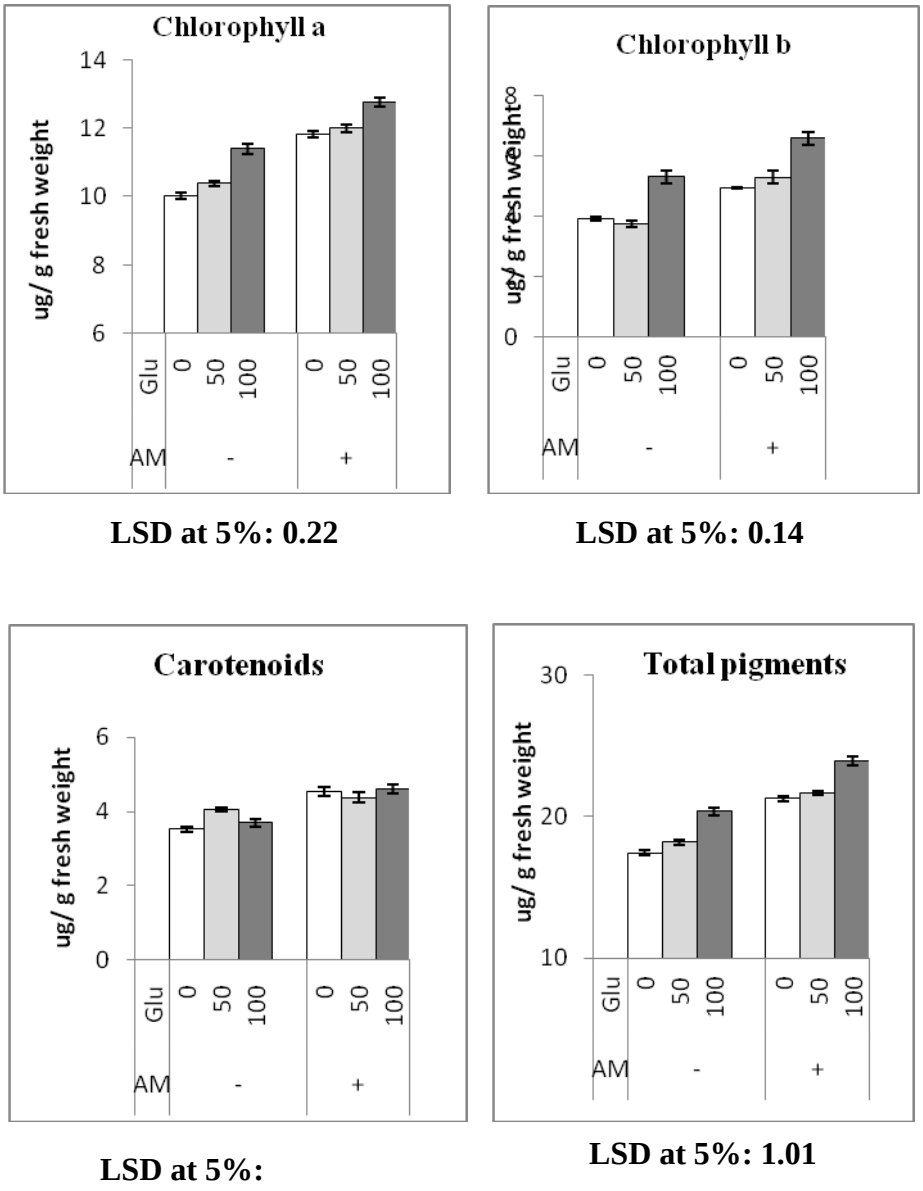

Figure 1: Effect of different concentrations of glutamic acid(0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments µg/g fresh weight) of wheat plant under newly reclaimed sandy soil. (at 75 days from sowing) Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Changes in IAA and total phenol contents:

Data in Fig. 2 showed that amended soil with AM caused significant increases in IAA and total phenol contents (the percentage of was 34% and 55% of IAA and total phenol respectively) as compared with untreated soil. Data also show that glutamic acid with different concentrations (50 and 100mg/l) caused gradual increases in IAA and total phenol contents as compared with control plants. Higher content of IAA and total phenol was obtained with 100 mg/lglutamic acid application. Data reviled that foliar treatment of glutamic acid in presence of AM caused significant increases in IAA and total phenol contents of wheat plant. These increases were more pronounced in presence of AM at 100 mg/l glutamic acid.

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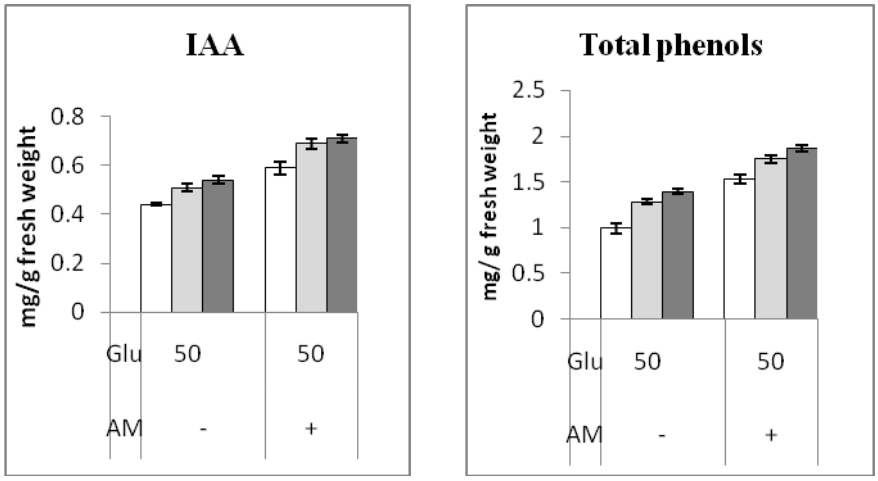

LSD at 5%: 0.12 **LSD at 5%: 0.08**

Figure 2: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on IAA and total phenol contents of wheat plant under newly reclaimed sandy soil. (at 75 days from sowing) Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Changes in carbohydrate constituents:

Data in Fig.3 showed that, AM addition to soil increased significantly TSS, polysaccharides and total carbohydrates of wheat plants as compared with those in absence of AM. Data also show significant increases in total soluble sugars, polysaccharides and total carbohydrate contents of wheat plant treated with different concentrations of glutamic acid. Application of 100 mg/l glutamic acid was the most effective treatment as it increased TSS by 43%, 55%, polysaccharides by 29%, 40% and 31%, 43% of total carbohydrates in absence and presence of AM respectively as compared with the untreated plant.

LSD at 5%: 131.15 **LSD at 5%: 213.33** **LSD at 5%: 78.66**

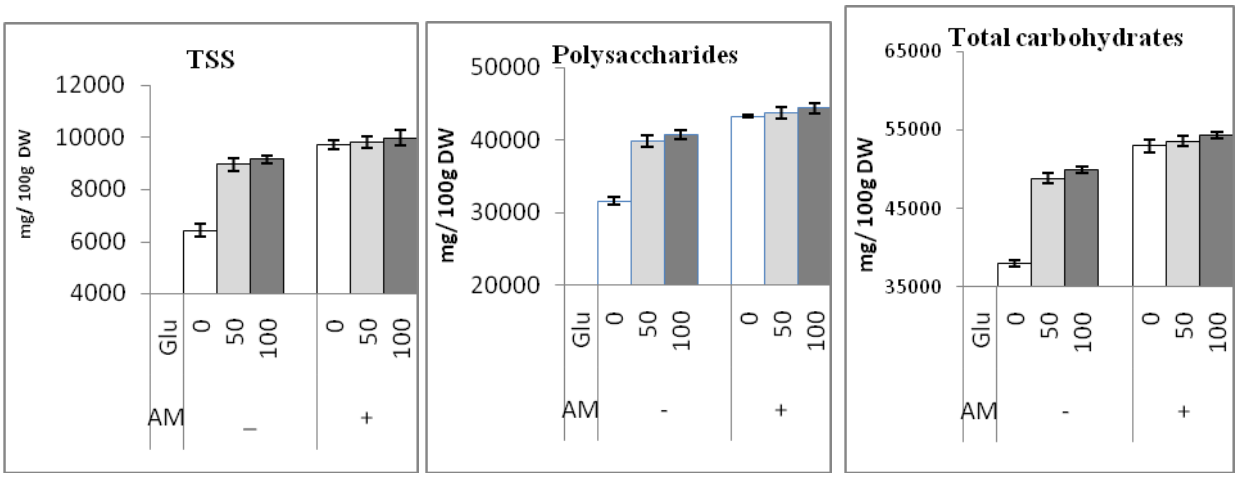

Figure 3: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on TSS, polysaccharides and total carbohydrates mg/ 100g dry weight) of wheat plant under newly reclaimed sandy soil. (at 75 days from sowing) Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Changes in yield and yield components:

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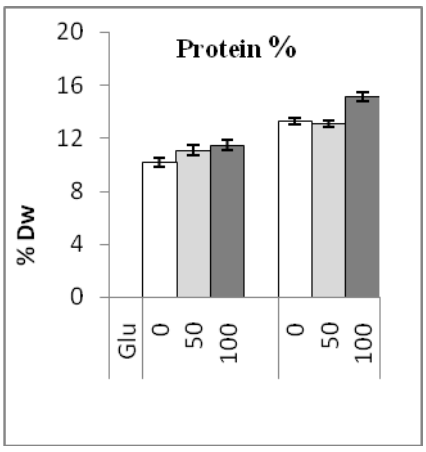
Yield and yield component of wheat plant affected by foliar treatment of glutamic acid in absence and presence of AM amended with soil are presented in (Table 3). Data revealed that AM treatment of soil increased significantly all yield components as compared to control plants (Table 3). Exogenously applied glutamic acid with 50 and 100 mg/l significantly increased yield and yield components (plant height (cm), spikelet no/spike, 1000 grains weight (g), grain yield /spike (g), straw yield (ton /fed), biological yield (ton/fed) and grain yield (ardabe/fed). Maximum yield and yield components were obtained in response to 100 mg/l as compared with control plant. The interaction effect of glutamic acid in presence of AM caused higher effect as it increased significantly all yield components.

Grain yield (Ardbe/fed)	Biological yield (ton/fed)	Straw yield (ton/fed)	Grain yield/ spike (g)	1000 grains weight	Spikelet no/spike	Plant height	Treatment	
							Glu	AM
10.50±0.27	4.10±0.10	2.89±0.08	2.40±0.12	43.60±0.26	16.20±0.40	71.30±0.66	0	-
13.50±0.16	4.46±0.08	2.93±0.06	2.90±0.06	48.30±0.17	16.90±0.26	75.60±0.85	50mg/l	
14.85±0.18	4.89±0.15	3.25±0.12	3.20±0.17	52.30±0.23	18.40±0.23	78.50±0.85	100 mg/l	
16.01±0.16	5.09±0.07	3.33±0.10	3.60±0.23	55.02±0.22	19.50±0.28	82.67± 0.14	0	+
16.54±0.17	5.17±0.16	3.50±0.11	3.90±0.15	58.20±0.38	20.30±0.37	85.70±0.37	50mg/l	
17.70±0.29	5.25±0.12	3.56±0.14	4.30±0.17	66.50±0.29	21.60±0.29	88.30±0.41	100 mg/l	
1.03	0.51	0.06	0.26	1.56	1.16	1.13	LSD at 5%	

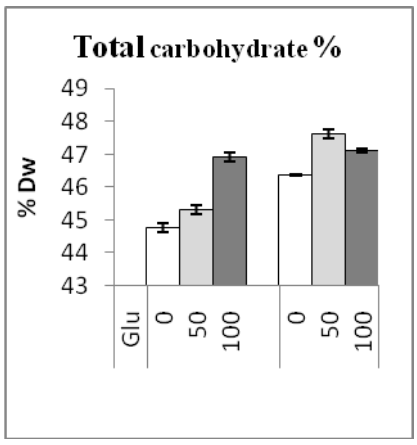
Table 3: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on yield and yield components of wheat plant under newly reclaimed sandy soil (mean of two season) . Each value represents the mean ± standard error (n =5).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Changes in carbohydrate and protein percentage in yielded grains:

Data in Fig.4 showed that, AM addition to soil increased significantly carbohydrates and protein % of wheat yielded grains as compared with those in absence of AM. Data also show significant increases in carbohydrates and protein % of wheat grain treated with different concentrations of glutamic acid. Application of 100 mg/l glutamic acid and AM was the most effective treatment as compared with the untreated plant and the other treatments.



LSD at 5%: 0.19



LSD at 5%: 1.73

Figure 4: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on total carbohydrates and protein % yielded grains of wheat under newly reclaimed sandy soil. Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

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Changes in macronutrient and micronutrient contents in yielded grains:

Regarding the effect of glutamic acid and AM application on nitrogen, phosphorus and potassium contents of wheat grains. Data presented in Fig. 5 revealed that, AM to newly reclaimed sandy soil increased significantly grain contents of nitrogen, phosphorus and potassium as compared with control plants. Foliar spraying of wheat plants with different concentrations of glutamic acid stimulated nitrogen, phosphorus and potassium contents of wheat grain compared with the control plant. Data also show that foliar treatment of glutamic acid (50 and 100 mg/l) to wheat plant and addition of AM were more effective as compared with those cultivated in absence of AM. Glutamic with 100mg/l was the most effective treatment as it gave the highest contents of nitrogen, phosphorus and potassium in presence of AM.

Regarding to micronutrient contents, Figure 5 presented the effect of foliar treatment of glutamic acid with different concentrations in absence and presence of AM on micronutrient contents (Fe^{++}, Mn^{++}, Zn^{++}) of the yielded wheat grains. Data clearly show that, addition of AM to the soil increased significantly all the studied micronutrient of the yielded grains. Data also show that, glutamic acid with different concentrations increased micronutrient contents of the yielded grains in absence and presence of AM.

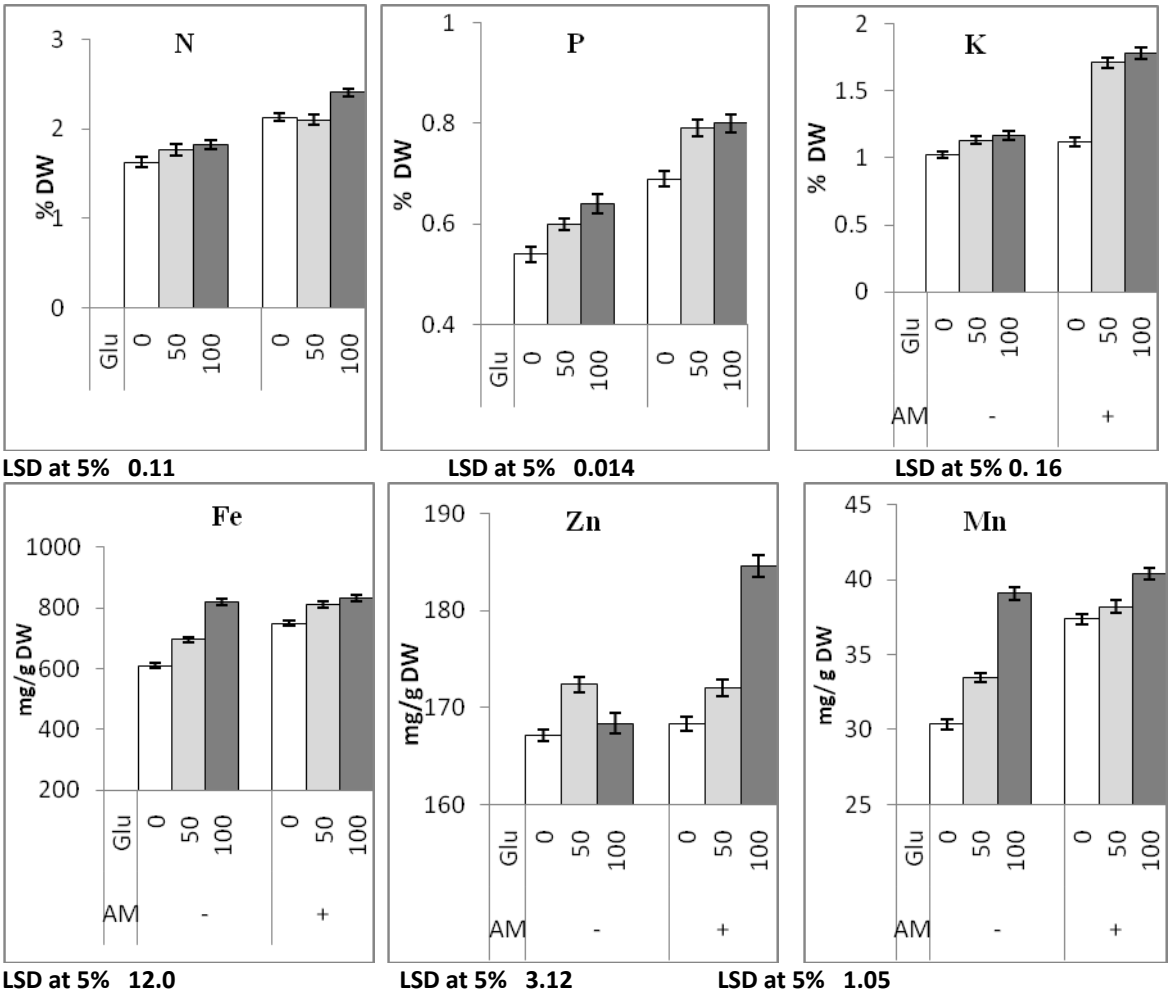

Figure 5: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on macronutrient (N, P, K,) and micronutrient (Fe, Zn, Mn) contents of wheat plant under newly reclaimed sandy soil. Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Total phenol and flavonoid contents in yielded grains:

Data in Fig.6 showed that, AM addition to soil increased significantly total phenol and flavonoids content of wheat yielded grains as compared with those in absence of AM. Data also show significant increases in total

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phenol and flavonoid contents of wheat grain treated with different concentrations of glutamic acid. Application of 100 mg/l glutamic acid and AM was the most effective treatment as compared with the untreated plant and the other treatments.

Antioxidant activity in yielded grains:

Data in Fig. 6 showed that amended soil with AM caused significant increases in antioxidant activity (as DPPH- radical scavenging capacity) of wheat as compared with untreated soil. Data also show that glutamic acid with different concentrations (50 and 100mg/l) caused gradual increases antioxidant activity as compared with control plants. Higher content of antioxidant activity was obtained with 100 mg/l glutamic acid application.

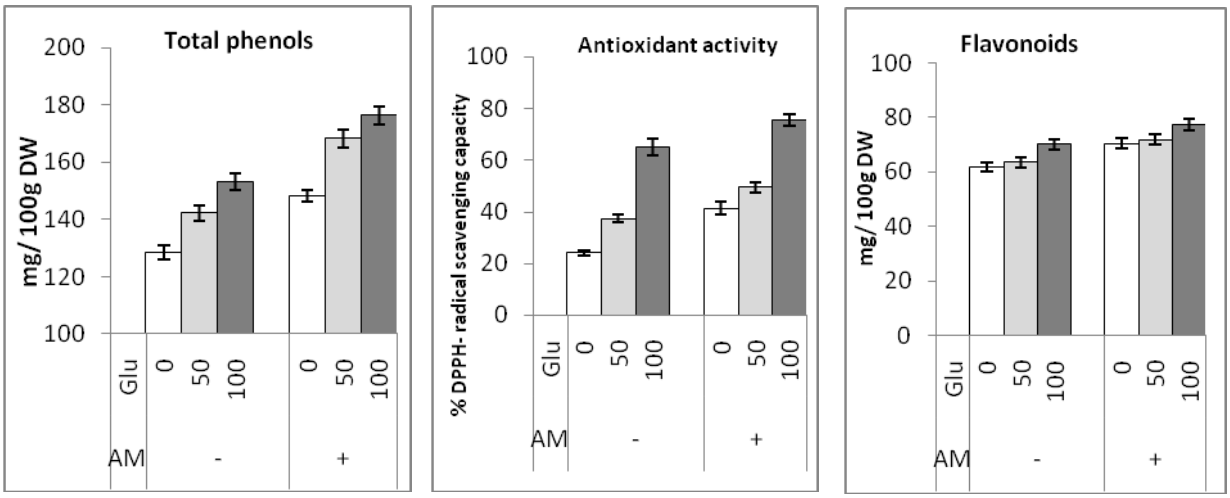

Figure 6: Effect of different concentrations of glutamic acid (0.0, 50 & 100 mg/l) in absence (-) or presence (+) of mycorrhiza on total phenols, flavonoids and antioxidant activity % yielded grains of wheat under newly reclaimed sandy soil. Each value represents the mean ± standard error (n =3).*Glu = Glutamic acid *AM = Arbuscular mycorrhiza.

Changes in amino acid composition in yielded grains:

The patterns of changes in the amino acid composition of the yielded grains of wheat plant treated with glutamic acid (50 and 100 mg/l) in absence and presence of AM are shown in (Table 4). Results revealed that, proline was the highest value among the amino acids (most predominant). Proline values ranged between 129.4: 237.5 followed by glutamic acid 115.0: 136.5, arginine 18.2 : 40.1, Aspartic acid 16.3 : 24.4 Cystine 12.78 : 35.7. These various amino acids are considered the predominant amino acids. While other amino acids are considered as minor amino acid. Addition of AM increased markedly amino acids, total essential amino acids (threonine, valine, methionine, leucine, isoleucine, phenylalanine, histidine, lysine and arginine) and total amino acids as compared with untreated wheat plant. Foliar treatment of glutamic acid at 100 mg/l increased markedly amino acid constituents and essential amino acids as compared with control plant. The interaction of glutamic acid and AM was more effective in amino acid constituents of wheat plant and total essential amino acids.

Table 4: Effect of different concentrations of glutamic acid (0.0 &100 mg/l) in absence (-) or presence (+)of mycorrhiza on amino acid contents of wheat plant under newly reclaimed sandy soil (mg/ 100 g dry weight). Each value is the ± SE.

With Mycorrhiza		Without Mycorrhiza		
100 mg/l	0	100 mg/l	0	Treatment
24.4 ±0.18	18.2 ±0.13	26.4 ±0.16	16.3 ±1.02	Aspartic acid
10.9 ±0.19	5.7 ±0.102	10.1 ±0.12	4.1 ±0.08	Threonine*
16.9 ±1.01	12.9 ±1.1	21.7 ±1.6	9.6 ±0.13	Serine
136.8 ±12.06	115.0 ±8.06	131.2±8.6	115.0 ±0.98	Glutamic
237.5 ±19.04	227.9 ±17.4	169.4±11.4	129.4 ±12.6	Proline

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14.9 ±0.18	8.7 ±0.08	13.5 ±0.099	6.8 ±0.04	Glycine
35.7 ±1.5	20.8 ±1.25	18.4 ±1.05	12. 8 ±0.91	Cystine
13.6 ±1.31	10.2 ±1.31	12.0 ±1.1	5. 7±0.067	Alanine
1.7 ±0.015	0.5 ±0.005	0.1 ±0.001	0	Valine*
1.6 ±0.014	0.7 ±0.005	1.7 ±0.055	0.8 ±0.005	Methionine*
20.4 ±0.19	11. 7±0.088	11.2 ±0.088	7.7 ±0.069	Leucine*
17.0 ±1.98	11.8 ±0.98	12.7 ±0.98	7.7 ±0.046	Isoleucine*
13.3 ±0.097	9.5 ±0.097	7.4 ±0.087	5.7±0.087	Phenylalanine*
6.4 ±0.062	4.7 ±0.062	2.1 ±0.0624	2.4 ±0.036	Tyrosine
6.7 ±0.55	5.6 ±0.25	4.4 ±0.258	3.6 ±0.054	Histidine*
8.0 ±0.54	5.7 ±0.113	7.6 ±0.113	2.7±0.044	Lysine*
40.1 ±1.87	20.7 ±2.2	36.8 ±2.97	18.2±1.01	Arginine
79.6	39.5	55.2	32.3	Essential A A*
526.3	439.1	431.5	316.2	Non essential A A
605.9	478.6	486.7	348.5	Total amino acids

DISCUSSION

Changes in growth criteria:

Addition of AM fungi to the newly reclaimed sandy soil increased significantly all the studied growth criteria of wheat plant as compared with control plants (Table 2). Also, foliar treatments of wheat plants with different concentrations of glutamic acid in absence and present of AM had a significant effect on all studied growth criteria. These results of AM fungi are in accordance with those obtained by Hafez, et al. (2013) on olive Cultivars. These increases in the studied growth parameters can be resulted from the effects of AM fungus on absorbing various nutriments such as nitrogen, calcium, potassium, copper, zinc, sulphur and especially better P nutrition (Sharifi et al., 2007**)**.Using AM fungus increases plant growth and affects devoting and transferring nutriments between stem and root so that dry weight of shoot is increased by increasing absorption of nutriment and their transfer. Plants and fungi interact naturalistically, while the plant receives mineral nutrients and water through the fungus, the fungus is supplied with carbohydrates by its host **(**Smith and Read, 2008**)**. These obtained results of glutamic acid are in line with those obtained by Haroun *et al.,* (2010) on *phaseolus vulgaris*, Mazher *et al.,* (2011) on *Codiaeum variegatum* and Omer *et al.,* (2013) on Chamomile. The positive effect of glutamic acid may be due to that, glutamic acid are an acceptable nitrogen source for increased growth rate of shoots. Thus, it can be stated that in the present study adequate amount of amides (of glutamic acid) after being hydrolyzed in the medium, were taken up in the tissues as ammonia, and consequently assimilated within wheat tissues and hence caused the observed increase in the various growth parameters. This increase may thus be directly related to the increased flux of amide to the leaf and/or to the subsequent reduction processes involved **(**Green *et al.,* 1990). In addition, the amides have been reported to induce effects like stimulation of cell wall formation, elongation of cells and increased cell division (Schröder *et al.,* 2005). In this concern, amino acids (as glutamic acid) are important for growth regulation and as modulators of growth and cell differentiation, which may be affecting general metabolism and consequently morphogenesis ***(***Basu *et al.,* 1989). Amino acids are of special interest to plant producer due to their wide range of roles in plant metabolism. Amino acids are not only building blocks of proteins but also precursors for a myriad of other molecules that serve important functions in plants. Amino acids are involved in the synthesis of other organic compounds, such as protein, amines, alkaloids, vitamins, enzymes, terpenoids and plant hormones that control various plant processes (Glawischnig *et al.,* 2000).

Photosynthetic pigments:

Data in Fig (1) show that, the leaves contents of photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments) significantly increased by addition AM compared with the untreated plants. In addition, data indicated that the glutamic acid treatments in absence and presence of mycorrhizal which were used in this study had significant effect on all photosynthetic pigments. With respect to mycorrhizal, similar results

were reported by Abdallah *et al.,* (2013) on sunflower plant. Most of the researchers suggested that AM symbiosis increased the units of photosynthesis, and so as to increase the rates of photosynthetic storage and export at the same time (Gemma *et al.,* 1997; Augé, 2001). Our obtained results of glutamic acid are in good harmony with those obtained using asparagines and glutamine on French bean plant **(**Haroun *et al.,* 2010**)** and using amino acid mix on faba bean plant *(*Sadak *et al.,* 2015). The observed progressive increases in pigment contents (chl a, chl b, carotenoids and total pigments) of wheat plant with different concentrations of either glutamic acid were in good support to the growth rate (Table 2) as well as to the change in carbohydrate content (Fig. 3) In this connection**,** Wettlaufer and Obendorf (1991*)* have reported that, treatment of soybean with glutamine or asparagine resulted in increasing fresh weight and retention of green color. Also, the positive effect of foliar amino acids on enhancing all photosynthetic pigments percentage may be due to the succnyl COA (Kerb's cycle intermediate) and the amino acid glycine, initiate the biosysnthetic pathway leading to chlorophyll formation **(**Taylor *et al.,* 1982).

Changes in IAA and total phenol contents:

Arbuscular mycorrhiza addition to soil caused significant increases in IAA contents (Fig. 2) Also, foliar treatment of wheat plant with glutamic acid with different concentrations (50 and 100 mg/l) caused gradual increases in IAA contents as compared with control plants. Our obtained data are in agreement with those obtained by Liu *et al.,* (2000) who found the inoculation of AM significantly increased the contents of IAA levels in leaves and roots of corn and cotton under drought conditions. Also, Haroun *et al.,* (2010) using glutamic acid on French bean**.** The increase in IAA content in shoot tissues treated with glutamic acid concurrent with the increase in growth rate (Table 2) indicates the role of the endogenous hormones in stimulation the cell division and/or cell enlargement and subsequently growth **(**Taiz and Zeiger*,* 2006). Similarty, Abdallah *et al.,* (2013) stated that, AM amended in soils increased IAA contents of sunflower plant. It was suggested that endogenous hormone balance changed by AM fungi colonization contributed to the enhancement of plant growth and yield.

Vesicular arbuscular mycorrhiza forms symbiotic relationship with 80% of land plants. It increases nutrient absorption capacity of plants and enhances plant defense mechanism. Data in (Fig. 2) showed that (AM) addition to soil caused significant increases in total phenol contents. Also, foliar treatment of wheat plant with glutamic acid with different concentrations (50 and 100mg/l) caused increases in total phenol contents as compared with control plants. Our obtained data are in agreement with those obtained by *Amoirm,*et al. (1977) found that exogenous nitrate, glutamine in the culture medium, increased amounts of total phenol. In addition, Omer *et al.,* (2013) using amino acid mix application to chamomile plant increased polyphenol contents. Manila and Nelson (2014) stated that, AM amended in soils increased phenol contents on tomato plants.

Change in carbohydrate contents:

Effect of foliar application with different concentrations of glutamic acid in absence and presence of AM are presented in (Fig.3) Data show that, addition of AM increased TSS, polysaccharides and total carbohydrates contents of wheat plant as compared with those in absence of AM. Regarding to mycorrhizal treatment our obtained data are in harmony with those of Abdallah *et al.,* (2013) on *Helianthus annuus L*. The increase in total carbohydrates is positively correlated with AM of the host plant as reported by Thomson *et al.,* (1990). Porcel and Ruiz-Lozano (2004) reported that the positive correlation between sugar content and AM is due to the sink effect of the fungus demanding sugars from the shoot tissues (Augé, 2001). The processes involved in the development of AM frequently lead to increased rates of photosynthesis and of carbon compounds to the root systems of host plants (Finlay and Söderström, 1992). The favorable effect of co-inoculation may be attributed to hydrolysis of starch to sugars in the co-inoculated plants. In addition, favorably adjusting the osmotic balance and increasing the contents of chlorophylls increases the rate of photosynthesis and carbohydrate synthesis (Swaefy *et al.*, 2007). Data also indicated increases in carbohydrates constituents as affected by different concentrations of glutamic acid treatments followed the same trend obtained previously on vegetative growth. These increases were gradually increased by increasing concentration of glutamic acid used. Those obtained data of glutamic acid are in good agreement of those obtained by Haroun *et al.,* (2010), Mazher *et al*., (2011) on different plant species. The promotive affect of the amino acids (glutamic acid) on carbohydrates constituents may be due to their role of biosynthesis of chlorophyll molecules which in turn affected total carbohydrates contents.

Changes in yield and yield components:

Treatments of wheat plant with the glutamic acid had a significant effect on yield and yield components (Table 3) in absence and presence of AM. However, all yield parameters were increased by the different levels of glutamic acid as compared with the untreated plants. With regard to AM the improved yield and yield components in wheat plants reported here demonstrate the potential of mycorrhizal inoculation to increase all yield components. Similar results were obtained in tomato grown under field conditions in semiarid areas of the world Al-Karaki *et al.,* (2004). Abdallah *et al.,* (2013), Heidari and Karami (2014) reported that mycorrhiza improved growth, yield, water status, nutrient content and quality of seeds of different plants when exposed to water stress. This increase in yield components can be resulted from the effects of mycorrhiza fungus on absorbing various nutriments such as nitrogen, calcium, potassium, copper, zinc, sulphur and especially better P nutrition **(**Sharifi *et al.,* 2007).Using mycorrhiza fungus increases plant growth and affects devoting and transferring nutriments between stem and root so that dry weight of shoot is increased by increasing absorption of nutriment and their transfer. Plants and fungi interact naturalistically, while the plant receives mineral nutrients and water through the fungus, the fungus is supplied with carbohydrates by its host (*Smith* and *Read,* 2008). The positive effect of glutamic acid on yield may be due to the vital effect of this amino acid stimulation on the growth and yield of plant cells. Our results are combatable with those obtained by Mahgoub and Talaat (2005) on *Pelargonium graveolens* L. and Abd El-Aziz and Balbaa (2007) on *Salvia farinacea* plants, they stated that application of amino acids led to the increments of flowering parameters and found that amino acids produced a high quality of inflorescences. The stimulatory effect were found to be correlated with the increase in content and activity levels of endogenous promoters particularly gibberellins and IAA which are known to promote linear growth of plant organs **(**Wilkins*,* 1989).

Changes in carbohydrate and protein contents in wheat grains:

The different treatments of glutamic acid and /or AM effectively increased the total carbohydrate and protein percentage of yielded wheat grains. Similar finding were obtained in different plant species in response to AM application (Soliman *et al.,* 2012 ; Abdallah *et al.,* 2013), who found that, total carbohydrate, and protein concentrations were increased in mycorrhizal wheat and Acacia saligna plants respectively. Haroun *et al.,* (2010) found that glutamic acid application increase carbohydrates and total protein. In addition, Mazher *et al.,* (2011) found that glutamic acid application increased carbohydrates of wheat plant in different plant organs.

Changes in mineral contents in in yielded grains:

Arbuscular mycorrhiza and/or glutamic acid increased significantly the macro and micronutrients contents of yielded grain (Fig.5). N and P% were significantly higher in co-inoculated plants compared to un-inoculated plants. Application of AM can help in better assimilation of nitrogen in the host plant. AM have been shown to have a positive influence on the composition of mineral nutrients (especially poor mobility nutrients such as phosphorus) of plants (Al-Karaki *et al.,* 2004) by enhancing and/or selective uptake of nutrients. Moreover, increased nutrients uptake in co-inoculated plants may be due to N metabolism brought about by changes in the enzymes associated with N metabolism, enhancing its uptake facilitated by the extensive hyphae of the fungus which allows them to explore more soil volume than the non-inoculated plants. Co-inoculated AM of wheat plants were able to maintain a higher osmotic potential of cells leading to the significantly rapid growth, enhanced nodulation parameters, N, P, K, Ca, total carbohydrates percentages and chlorophyll contents as well as proline in leaves (Soliman *et al.,* 2012). Potassium plays a key role in plant metabolism it activates a range of enzymes. Accordingly, the response of AM- inoculated plants to stress and K+ content are closely related. This is primarily regulated by the supply of nutrients to the root system (Giri and Mukerji, 2004) and increased transport (absorption and/or translocation) by AM (Sharifi *et al.,* 2007). The adjustment of leaf osmotic potentials requires intracellular osmotic balance (Lee and George 2005) showed that mycorrhizal hyphae of *G. mosseae* had a significant contribution in the uptake of P and Zn by inoculated cucumber plants resulting in an increase concentration of those nutrients in the plant.

Furthermore, glutamic acid in generally stimulated the accumulation of total nitrogen contents in wheat. It could be concluded that the simulative effect of glutamic acid is through enhancing the biosynthesis of free amino acids and their incorporation into protein (Fig. 4). These results supported by the results obtained by Bassouny *et al.,* (2008). The respective increase in inorganic ion contents (K^+) at low and high concentration of

glutamic acid is expected to be influenced by the effect of nitrogen compounds on protein synthesis, as proteins are required to transport protons, inorganic ions and organic solutes across the plasma membrane and tonoplast at rates sufficient to meet the needs of the cells (Schroeder *et al.,* 1999). In addition, multiple membrane proteins may be needed for cations uptake from soil or solution to adopt varying extracellular conditions and nutrient availability (Chrispeels *et al.,* 1999). Positively charged macronutrients such as potassium (K^+) are required in relatively large amount for plant growth and development. Thus, the above mentioned results are consistent with the results of growth parameters (Table 2) and also with pigments (Fig.1). This means that glutamic acid influence the absorption and transport of cations, as reported by Robinson *et al.,* (1983). Glutamic acid led to increase in the contents of ions in the main organs of the wheat plant through their role in regulating various processes including absorption of nutrients from soil solution (Buschmann and Lichtenthaler*,* 1979).

Additional cationic micronutrients (Fe^{++}, Mn^{++}, Zn^{++}) play essential roles as cofactors and activators of enzymes. Increasing the Zn^{++} and Fe^{++} concentration in food crop plants, resulting in better crop and improved human health is an important global challenge **(**Welch and Graham 2004**).**

Total phenols content in yielded grains:

Data in Fig. 6 showed that arbuscular mycorrhiza addition to soil and/or glutamic acid increased significantly the phenols content of wheat grain. Our obtained data are in agreement with those obtained by Amoirm*,et al*., (1977) found that exogenous nitrate, glutamine in the culture medium, increased amounts of total phenol. Also, Manila and Nelson (2014) stated that, AM amended in soils increased phenol contents on tomato plants.

Total flavonoids content in yielded grains:

Data represented in Fig. 6 indicated that glutamic acid (50 and 100 mg/l) in absence and presence of AM for significant and pronounced increase in total flavonoids content. The importantce of the flavonoids was known to possess significant antimicrobial activities and was utilized as natural plant protectants **(**Weidenbomer *et al.,* 1992**).** It could be suggested that flavonoids content may be an alternative to conventional fungicides in the control of storage grains against some fungi.

Antioxidant activity in yielded grains:

Data in Fig. 6 showed that (AM) addition to soil caused significant increases the antioxidant activity (as DPPH- radical scavenging capacity) of wheat grain. Also, foliar treatment of wheat plant with glutamic acid with different concentrations (50 and 100mg/l) caused increases in the antioxidant activity as compared with control plants. Yu*, et al.,* (2002) suggesting that significant levels of antioxidant activities and phenolic components have been detected in wheat and wheat-based food products and indicating that wheat may serve as an excellent dietary source of natural antioxidants for disease prevention and health promotion. The increase in the scavenging activity can be considered an advantage of treatment used. This could be attributed to the increases in total phenols and total flavonoids **(**Zilic, *et al.,* 2011**).**

Amino acid composition in yielded grains:

It has been found in the present investigation that, wheat plant cultivated in soil amended with AM gave higher amino acids, essential amino acids (threonine, valine, methionine, leucine, isoleucine, phenylalanine, histidine, lysine and arginine) and total amino acids as compared with soil without AM. Manila and Nelson (2014) stated that, total amino acid concentration was higher in tomato plants inoculated with mycorrhiza than that of non-inoculated ones. Also glutamic acid foliar treatment increased the contents of total amino acids, essential amino acids and the ratio of essential to non-essential amino acids compared with control plants. These obtained results are in harmony with those obtained by Hassanein *et al.,* (2013) who reported that, amino acid treatment enhanced the levels of total amino acids, essential amino acids and the ratio of essential to non-essential amino acids in wheat plant. This could be confirmed by the results obtained in the present work which indicated an increase in aspartic, glutamic and arginine and decrease in NH^{+4} (data non-shown) content in wheat treated with AM and glutamic acid. Glutamic could be converted directly to proline, **(**Santa–Cruze *et al.,* 1999**)** or indirectly through the metabolic flux from glutamate under stress conditions which known to be highly in favor of proline

synthesis through the glutamate Δ1 – sreported that arginine and proline accumulation as a result of amino acid application are considered to be detoxification mechanism to NH^{+4} produced in plants subjected to stress S untreated wheat plant amino acid contents.

CONCLUSION

This paper summarizes effects of mycorrhiza and/or glutamic acid on morphology, metabolism and protective adaptation and increased the nutritional values of host plants in the condition of new reclaimed sandy soil. Mechanism that mycorrhiza and/or glutamic acid can improved growth in host plant may include many possible aspects: mycorrhiza activates defense system of host plant quickly by stimulating growth regulators level which may be induced a potent effect in regulating the growth in plants and involved in protecting the photosynthetic apparatus and consequently increasing the photosynthetic pigments and thereby resulted in a significant improvement physiological and biochemical parameters as well as total contents of soluble sugars, phenols, proline, amino acids. Moreover, wheat plant cultivated in soil amended with AM and glutamic acid gave higher nutritional value of macronutrients and micronutrients (N, P, K, Fe, Zn & Mn), carbohydrate%, protein%, total flavonoids, phenol, antioxidant activity, total amino acids and total essential amino acids in yielded grains. Its success depends partly not only on its adaptability and high yield potential but also on the gluten and protein which confers the viscoelastic properties that allow dough to be processed into bread, pasta, noodles, and other food products.

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