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ORIGINAL ARTICLE

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Effect of Different Levels of Glycine on Growth and Yield of Two Potato Cultivars under Field Conditions

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This field investigate was conducted in 2021 and 2023 to evaluate the response of two potato cultivars to different levels of glycine in terms of plant dry mass (PDM), yield, total sold solutions (TSS), and some miniral elements analysis from aerial parts of potato plants. Two potato cultivars namely, Spunta and Larissa were exposed to three levels of glycine (0.0, 1.5 and 3.0 mM). Trial pieces were conducted as a factorial based on a randomized complete block design with three replications. glycine treatments led to significant effects on most characters, i.e., PDM and yield of two potato cultivars were significantly increased in all concentrations of glycine as compared to the control. As well, P content was increased by foliar application of glycine in all levels. but, K and Fe content in aerial parts were decreased. Also, a positive correlations were found among N and K, or/and K and Fe elements. Moreover, the results of this research revealed that increasing levels of glycine have positive effects on growth, biomass and yield of potato cultivars.

Key words: Potato. Glycine. Plant dry mass. Yield

Abbreviations: PDM plant dry mass, TSS total sold solutions, N nitrogen, P phosphorus, K potassium, Na sodium, Zn zinc, Fe iron.

A potato yield losses in the world, as a result of climate alteration is expected to range between 18 and 32% during the first three decades of this century (Hijmans, 2003; Monneveux *et al*., 2014). Drought, salinity, low and high temperatures are the most important limiting factors among different environmental constraints which induce plant stress and reduce crop productivity in many parts of the world (Lawlor, 2002). Generally, a great challenge in the future, rises demand for nutrition products and for fresh water resources because of increasing a predicted world population of 9 billion by 2050 and altered food behaviors (Costa *et al*., 1997; Araus *et al*., 2008; Singh *and* Kaur, 2009; Levy *et al*., 2013; Lobell *et al*., 2008), also, growing crisis in many parts of the world i.e., COVID-19 and wars.

However, potato (*solanum tuberosum* L.) is presented in the fourth greatest main food crop after wheat, maize and rice (Singh *and* Kaur, 2009). In agriculture there are many procedures that have been proposed and used widely to inhance mineral nutrition of plants under regular or stress conditions (Pérez-Jiménez *et al*., 2015; Sánchez *et al*., 2005), i.e., inorganic fertilizers have an inevitable role in food production of agricultural crops (Souri *and* Hatamian, 2019). Furthermore, nitrogen is an essential macroelement for plant growth and development. As well, plants are required it in the largest quantities for their metabolisms and represents up to 2% of plant dry mass (Masclaux-Daubresse *et al*., 2010). In addition, because of the main source of N for plants are nitrate, they absorb it from agricultural soil in the form of nitrate and ammonium, while organic N such as amino acids, can also be taken up by plants (Nasholm *et al*., 2009). Moreover, organic nitrogen must be converted into nitrate or ammonium prior to become biologically available (Gonzalez-Perez *et al*., 2015), and which represents 96–99% of total nitrogen in soil, could be directly absorbed by plants and significantly influence plant physiology and nutritional quality (Paungfoo-Lonhienne *et al*., 2008).

In the other hand, amino acids characterize a main part of the low-molecular weight organic N that is dissolved in the soil. The existence and concentrations of different amino acids vary significantly from one ecosystem to another. In general, these compounds are found at low concentrations in the soil, ≈0.01 to 10 mM (Jones *et al*., 2005). Plus, amino acids have various important biological functions in plant cells including detoxification of toxins and heavy metals (Hussain *et al*., 2018; Rizwan *et al*., 2017; Bashir *et al*., 2018), optimizing the nutrient uptake, translocation and metabolism, vitamin biosynthesis, growth biostimulation, contribute in the tolerance of plants to environmental stresses such as drought, salinity, high and low temperatures, other than in the synthesis and production of aminochelate fertilizers (Jeppsen, 1991; Sharma *and* Dietz, 2006; Souri *and* Hatamian, 2019). Furthermore, amino acids have been shown to improve plant growth, yield, and nutrient uptake (Garcia *et al*., 2011). In these patches, glutamic acid, serine, glycine, alanine, and aspartic acid are the most abundant amino acids (Lipson *and* Nasholm, 2001). Conversely, the simple amino acid (glycine has a single hydrogen atom as its side chain with the chemical formula NH_2-CH_2-COOH is regarded as a proof of life), was the original nutrient form for organisms (Xu *et al*., 2017) and is one of the most plentiful free amino acids in agricultural soil. Also, the glycine concentration of soil ranges from 1.14 to 2.39 µg N/g, corresponding to more than 30% of total free amino acids (Wang *et al*., 2013; Gonzalez-Perez *et al*., 2015). However, this research was conducted to study the response of growth and yield of two potato cultivars to different levels of glycine under field conditions.

MATERIALS AND METHODS

Plant material, growing conditions and experimental design

In this investigate, a field experiment was conducted as a factorial based on a randomized complete block design with three replications and carried out from the Februry to April 2021 and 2023 for two years at Algotta research station of general commission for scientific agriculture research, located in Damascus, Syria (33º 24.64' N, 36º 30.87' E and 616 m above the mean sea level) to examine the effects of application of three levels of amino acid 'glycine' (0.0, 1.5, and 3.0 mM) on two potato cultivars (Spunta and Larissa). Tubers (about

50-70 gr) were kept at room temperature of 25°C for two weeks to germinate and then cultivated in the soil with deminshes 25 cm between plants and 75 cm between rows. Before planting, some samples of the medium culture were prepared for analyzying (table 1). All plants were irrigated normally. Therefore, glycine treatments were applied at the stage of beginning flowers. At the end of the experiment (i.e., 110 days) all parts of potato plants were collected for analyzying.

Plant dry mass

At the end of this research, aerial parts of potato plants (shoots and stems) of each cultivar and in each block and replicate were dried to specify a fixed dry weight.

Yield

The harvest of tuber yield of potato cultivars and calculations (t/h) were done alone in each block and replicate.

Total soluble solids (TSS)

Tubers samples of potato cultivars were collected randomly and the TSS measurements were done by using a field device (Refractometer).

Analysis of ions

Shoots of plants were dehydrated and digested in an acid mixture consisting of sulfuric, nitric and per-chloric acids in the ratio of 1:8:1 (v/v). The aliquot was filtered and used for determination of K, Na and with Flame photometer (Allen *et al*., 1986). Nitrogen was measured using micro Keldahl method (Jackson, 1958) and the P concentration of plant samples was determined, by colorimetrically after nitric perchloric digestion method (Hanson, 1950).

Oven dried grinding 0.5 g sample was taken into 50 ml conical flask and 5 ml HNO_3+ $HClO_4$ was added into it. After that, it was transferred into digestion chamber for 2.5 hours. Then it was cooled down. Again, 20 ml of distilled water was added and heated with digestion chamber at 280 ºC for 30 minutes. The solution was then transferred into 100 ml volumetric flask with filter paper and made the volume 100 ml (stock solution). 5 ml extract solution in addition with 20 ml distilled water was taken into 50 ml volumetric flask. Then, At last, 1 ml $LnCl_2$ was added and the volume was made 50 ml with distilled water. Finally, reading of Na^+ and K^+ was taken by atomic absorption spectrophotometer (Bar-Tal *et al*., 1991). By atomic absorption spectrometry (Perkin Elmer, Waltham, MA model 5000 spectrophotometer), the concentrations of Zn and Fe were determined (Allen *et al*., 1986).

Data analysis

To determine the difference among treatments and between cultivars, the mean data of two years were tested and subjected to analysis of variance (ANOVA) by using SAS and MSTATC programs, and conducted as a factorial based on a randomized complete block design with three replications. Comparison of means was achieved by using LSD test ($p < 0.05$) and the correlation coefficients between the characters were done by using PROC CORR of SAS program.

RESULTS

Analysis of variance for plant dry mass (PDM), potassium (K) and iron (Fe) of potato cultivars revealed statistical significance ($p < 0.01$) between cultivars. As well as, these statistical significances ($p < 0.01$) between treatments were shown for PDM, yield, phosphorus (P) and Fe. As well, analysis of variance for total soluble solids (TSS) was not significant in the studied cultivars, treatments and between interactions treatments and cultivars (table 2).

Plant dry mass and yield

The interaction effects of cultivars and glycine levels were significant ($p < 0.01$) on plant dry mass (PDM) and ($p < 0.05$) on yield of potato cultivars (table 2). Under regular conditions of irrigation, the maximum and minimum values of PDM were attained in Spunta (93.3 g/plant) and Larissa (80.0 g/plant), and yield were achieved in Larissa (38.99 t/h) and Spunta (31.3 t/h). On the other hand, under glycine treatments (1.5 and 3.0 mM), the maximum and minimum values of PDM were obtained in Spunta (153.3 g/plant) and Larissa (116.7 g/plant) in the treatment 3.0 mM, likewise, yield in Larissa (52.52 and 40.96 t/h) in the treatment 3.0 and 1.5 mM, respectivily (table 5). PDM and yield were significantly increased in the tested cultivars at 1.5 and 3.0 mM of glycine treatments compared to the conrtol under normal conditions. Maximum increasing were observed at 3.0 mM of glycine treatment (55.71 % and 44.0 %) for PDM and yield as compared to the normal conditions, respectivily (table 3). On the other hand, PDM of Spunta was increased by 20 % as compared to Larissa cultivar (table 4).

Table 1 Physical and chemical properties of the experimental soil.

pH	EC (dSm^{-1})	CaCo3 (%)	Available K (mg kg^{-1})	Available P (mg kg^{-1})	Total N %	Tissue of soil	Organic content %	Mechanical analysis %		
								Sand	Silt	Clay
8.4	0.92	50.2	453	336	0.14	clay	2.68	20	23	57

Table 2 Analysis of variance for plant dry mass (PDM), yield, total sold solutions (TSS), nitrogen (N), phosphorus (P), potassium (K), sodium (Na), zinc (Zn), iron (Fe), cultivar (Cult), treatment (Treat) and replication (Rep) of potato cultivars evaluated at three levels of glycine.

Source of variation	Mean square										
	df	PDM (g)	Yield (t/h)	TSS	N (%)	P (%)	K (%)	Na (mg/kg)	Na/K	Zn (mg/kg)	Fe (mg/kg)
Cult	1	1440**	14.87^{ns}	0.056^{ns}	1.78*	0.0004^{ns}	2.52**	0.0005^{ns}	14.75**	255.53*	3578169**
Treat	2	4128**	361.16**	0.39^{ns}	0.72^{ns}	0.008**	0.036**	0.0002^{ns}	1.55**	26.11^{ns}	831060**
Rep	2	17.39	49.97	0.187	0.447	0.0003	0.0004	0.0005	0.015	35.82	8448
Treat*Cult	2	431.7**	74.59*	0.271^{ns}	0.648^{ns}	0.001^{ns}	0.013*	0.00004^{ns}	1.49**	89.55^{ns}	1003115**
Error	10	20.9	17.3	0.42	0.26	0.0004	0.002	0.001	0.026	51.44	22967
C.V	-	3.9	9.6	11.84	19.84	19.85	8.75	8.05	12.97	8.20	10.76

** Significant at $P < 0.01$, * Significant at $P < 0.05$, ^{ns}: non-significant, respectively.

Table 3 Analysis of variance for plant dry mass (PDM), yield, phosphorus (P), potassium (K), and iron (Fe) of potato cultivars evaluated at three levels of glycine.

Treatment	PDM (g)	Yield (t/h)	P (%)	K (%)	Na/K	Fe (mg/kg)
0.0 mM	86.67^{c}	35.15^{c}	0.06^{b}	0.660^{a}	0.685^{c}	1627^{a}
1.5 mM	128.5^{b}	43.97^{b}	0.122^{a}	0.532^{b}	1.41^{b}	1619^{a}
3.0 mM	135.0^{a}	50.62^{a}	0.132^{a}	0.520^{b}	1.66^{a}	978^{b}
Variances, %	+44.75 +55.71	+25.1 +44.0	+103.3 +120	-19.4 -21.21	+105.8 +142.3	-0.5 -40.0
LSD %	5.8	5.35	0.027	0.064	0.21	195

.Mean followed by the same letter in each column are not significant different according LSD test (probability level of 5 %)

Table 4 Analysis of variance for plant dry mass (PDM), nitrogen (N), potassium (K), zinc (Zn) and iron (Fe) of potato cultivars evaluated at three levels of glycine.

Cult	PDM (g)	N (%)	K (%)	Na/K	Zn (mg/kg)	Fe (mg/kg)
Spunta	20.22^{a}	5.78^{a}	35.56^{a}	1.10^{a}	23.50^{b}	1854^{a}
Larissa	16.17^{b}	3.39^{b}	25.78^{b}	0.96^{b}	29.04^{a}	962^{b}
Variances, %	+20.03	+41.35	+27.5	+12.73	-23.6	-48.1
LSD %	5.87	0.69	2.49	0.08	2.84	159

.Mean followed by the same letter in each column are not significant different according LSD test (probability level of 5 %)

Table 5 Analysis of variance for plant dry mass (PDM), yield, potassium (K) and iron (Fe) of potato cultivars evaluated at three levels of glycine.

Cult	PDM (g)			Yield (t/h)			K (%)			Na/K			Fe (mg/kg)		
	0.0 mM	1.5 mM	3.0 mM	0.0 mM	1.5 mM	3.0 mM	0.0 mM	1.5 mM	3.0 mM	0.0 mM	1.5 mM	3.0 mM	0.0 mM	1.5 mM	3.0 mM
Spunta	93.3^{d}	130.3^{b} (+28)	153.3^{a} (+39)	31.3^{d}	46.97^{ab} (+50)	48.72^{a} (+56)	0.98^{a}	0.93^{a}	0.92^{a}	0.34^{d}	0.35^{d}	0.36^{d}	2437^{a}	1622^{b}	1503^{b}
Larissa	80.0^{e}	126.7^{b} (+58)	116.7^{c} (+46)	38.99 c	40.96^{bc} (+5)	52.52^{a} (+35)	0.34^{b}	0.13^{c}	0.12^{c}	1.03^{c}	2.48^{b}	2.97^{a}	818^{c}	1615^{b}	454^{d}
LSD %	8.32			7.57			0.081			0.293			275.7		

.Mean followed by the same letter in each column are not significant different

Table 6 Correlation coefficients of different traits and cultivars.

Traits	PDM	Yield	TSS	N	P	K	Na	Na/K	Zn	Fe
PDM	1	-	-	-	-	-	-	-	-	
Yield	0.54**	1	-	-	-	-	-	-	-	
TSS	0.01^{ns}	-0.27^{ns}	1	-	-	-	-	-	-	
N	0.31^{ns}	-0.05^{ns}	-0.32^{ns}	1	-	-	-	-	-	
P	0.85**	0.49*	-0.01^{ns}	0.22^{ns}	1	-	-	-	-	
K	0.23^{ns}	-0.22^{ns}	-0.09^{ns}	0.45*	-0.01^{ns}	1	-	-	-	
Na	-0.21^{ns}	0.05^{ns}	0.10^{ns}	-0.52*	-0.23^{ns}	-0.26^{ns}	1	-	-	
Na/K	-0.03^{ns}	0.32^{ns}	0.11^{ns}	-0.56**	0.20^{ns}	-0.92**	0.31^{ns}	1		
Zn	-0.12^{ns}	0.18^{ns}	-0.03^{ns}	-0.45^{ns}	-0.17^{ns}	-0.52^{ns}	0.15^{ns}	0.60**	1	
Fe	0.08^{ns}	-0.57**	0.001^{ns}	0.44^{ns}	-0.001^{ns}	0.69**	-0.29^{ns}	-0.59**	-0.37^{ns}	1

Plant dry mass (PDM), total sold solutions (TSS), nitrogen (N), phosphorus (P), potassium (K), sodium (Na), zinc (Zn), iron (Fe).

Elements analysis of the aerial parts of potato plants

The interaction effects of cultivars and glycine levels were significant ($p < 0.05$, $p < 0.01$) on K and Fe contents, respectivily (table 2). Under normal conditions of irrigation, the highest and lowest values of K were attained in Spunta (0.98 %) and Larissa (0.34 %), and Fe were achieved in Spunta (2437 mg/kg) and Larissa (818 mg/kg). On the other hand, under glycine treatments (1.5 and 3.0 mM), the maximum and minimum values of K were obtained in Spunta and Larissa at the treatments 1.5 and 3.0 mM of glycine. likewise, Fe (1622 mg/kg) in Spunta at the treatment 1.5 mM and Larissa (454 mg/kg) at the treatment 3.0 mM of glycine (table 5). K and Fe were significantly decreased in the tested cultivars by increasing levels of glycine compared to the normal conditions. But, regarding to the P element, our results revealed increasing values by increasing levels of glycine as compared to the control (table 3). Then again, the higher values of N, K and Fe were found in Spunta as compared to Larissa cultivar. But, the opposite results were found in Zn element (table 4).

Relationship between the traits

Correlation coefficients between of different traits and cultivars were calculated and are presented in table 6. Our results revealed that PDM was highly and positively correlated with yield and phosphorus. Also, a positive correlation was found between potassium and nitrogen, as well, between potassium and iron (table 6).

DISCUSSION

Amino acids such as, glycine and glycine betaine were discovered in a wide varieties of microorganisms and higher plants (Rhodes *and* Hanson, 1993). As well, they are considered as an organic osmolites that clearly gathers in many plant species and they found to be plentiful in chloroplasts, which plays a main role in regulating, protecting the thylakoid membrane and consequently maintaining the amount of photosynthesis (Genard *et al*., 1991).

However, similar to the findings Noroozlo *et al*., (2019) on Lettuce and sweet basil, and Shooshtari *et al*., (2020) on cucumber, our results indicated that PDM and yield of two potato cultivars were increased by increasing levels of glycine. The maximum increaseing of PDM was observed in Spunta cultivar by 39% and 28% at the treatments of glycine 3 and 1.5 mM respectivily, and Larissa by 58% at the treatment 1.5 mM as compared to their controls (table 5). On the other hand, yield was increased in Spunta cultivar by 56% and Larissa by 35% at the treatment 3 mM as compared to their controls (table 5). Similarly, our results showed highly and positively correlated between plant dry mass and yield (table 6). In fact, glycine is one of the main amino acids that is essential for protein biosynthesis in plant cells (Ma *et al*., 2017). As well, many studies indicated that foliar application of glycine can increase chlorophyll biosynthesis and photosynthetic rates resulting in improved plant growth (Garcia *et al*., 2011). Also, other investigations showed that amino acids could affect not only plant nitrogen metabolism, but also carbon metabolism due to their strong interactions (Nunes-Nesi *et al*., 2010) and in the result, plant growth and yield of crops could be improved (Zhang *et al*., 2015).

Conversely, in this research, we obsearved increasing in P by about 120% in potato plants at the treatment 3 mM as compared to the control (table 3). Moreover, our results indicated that K and Fe were decreased by increasing levels of glycine in all treatments, accept Fe values in the culivar Larissa at the treatment 1.5 mM (table 3 and 5). The maximum decreasing of K and Fe were 21 and 40% at the treatment 3 mM as compared to the controls (table 3). As well, the positive corrolation between K and Fe indicats that increasing levels of K leads to increasing levels of Fe conversely (table 6). However, results of Shooshtari *et al*., (2020) on cucumber plants revealed that there is no significant effect on the leaves content of K and Fe elements between the treatments of foliar application of glycine and control. Nevertheless, study of Noroozlo *et al*., (2019) on lettuce displayed significant increasing of Fe percent at the treatment 1000 mg/L of glycine, while its percent in the other concentrations of glycine was decreased and they noticed that there is no significant effect as compared to the control.

On the other hand, P is an essential macro-nutrient for growth and development in all living organisms. It serves various basic biological functions as a structural element, in energy metabolism, in the activation of metabolic intermediates, in signal transduction and in the regulation of enzymes. Likewise, K does an activator of many enzymes, share in synthesis of amino acids and proteins, opening and closing of stomata. As well, Fe intervenes in chlorophyll synthesis, cytochromes and nitrogenase (Vreugdenhil *et al*., 2007). Then again, at the end of potato plants cycle, K is playing a main role in transporting nutrition materials from the aerial parts to the tubers. In fact, amino acids such as glycine improve chlorophyll biosynthesis and photosynthesis rates and enhance protein biosynthesis and in the result, they are improving growth and development of plants (Khan *et al*., 2012; Souri *and* Hatamian, 2019).

CONCLUSION

In the present study, we have been able to gather evidence that foliar application of glycine in all levels increased plant dry mass and yield of potato plants. As well, concentration of glycine, 3 mM was more effective as compared to the other levels. However, our outcomes recommend that amino acids: Case of glycine, are effective to improve plant growth and yield of potato cultivars.

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CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

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