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Response of Potato Plants (*Solanum tuberosum* L.) To Foliar Application with Proline and Chitosan

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Abstract: This field experiment was carried out during two summer seasons of 2016 and 2017 at the Experimental Station, Faculty of Agriculture, Cairo University to investigate the effect of proline (0.15, 0.2 g/l) and chitosan (0.25, 0.5g/l) as foliar application on growth and yield of potato plants (*Solanum tuberosum* L.) cv. Lady Rosetta under unfavorable condition of late planting in mid-February. The foliar application was applied after 45 days from planting and then repeated three times interval every 10 days. Results show that foliar application of proline at 0.15g/l and chitosan at 0.25g/l recorded the highest plant height. Moreover, all treatments caused a distinct increment in tuber yield and economic yield (EY) as well as tuber content of nitrogen, potassium and protein. Proline at 0.15 or 0.2g/l as a foliar application recorded the maximum tuber content of phosphorus.

Key words: Proline · Chitosan · Potato (*Solanum tuberosum* L.) · Late planting

INTRODUCTION

Increasing human activity has led to increase thermal emissions and thus to high heat on the earth. Climatic changes and abiotic stresses led to limits the efficiency of plant growth [1]. Lower food production [2] high temperature one degree in average growth temperature causes a 17% reduction in yield, lead water loss and dehydration, which interferes with the lack of moisture in the soil [3, 4]. Affects membrane permeability, which cause the leaves to form some compounds (thermal stable proteins) to maintain the osmotic to escape from the high temperature [5, 6]. High temperature causes proteins and enzymes denaturation, leaves burning, inhibits growth and senescence and therefore lack of yield [7-9]. For that plant cells produce enzyme and antioxidants to reduce heat stress damage [10]. Free proline accumulates as response of heat stress [6]. Proline is a kind of nitrogen storage [11]. Consider one of the osmoprotectant compounds. Which, a mechanism of stresses tolerance, enzyme regulator, increase the activity of antioxidant enzymes, protect cell membrane and enhanced the leaves water content [12-17]. When plants exposed to abiotic stress, they accumulate proline as a physiological reaction works to maintain the osmotic in the cell [18]. Resistance of stresses dehydration and salinity by balancing the cell osmotic, allowing the plant to absorb water and nutrients [19]. Exogenous application of proline improves plant tolerance to avoid the temperature stress harmful effect [20]. Thus, prevents the occurrence of physiological damage [21].

Chitosan is an environmentally friendly natural substance produced from shellfish. Chitosan is derived from chitin and is a safe substance for humans and animals and is widely used in agriculture [22]. The use of chitosan in the past was limited to the coating and protection from diseases, but it has a role in improve growth and increasing the yield and reduce the harmful of stress. Chitosan has a role in plant resistance to negative effect of high and low temperature [23]. Also, Abu-Muriefah [24] suggested that chitosan is a promising substrate to avoid the effect of drought on growth and yield of *Phaseolus vulgaris*. In this respect, Farouk and Ramadan [2] indicated that chitosan application removed the harmful effect of drought in Cowpea plants by enhancing stomatal conductance. Chitosan considered an antioxidant and scavenge the free radicals to protect the cell [25, 26]. Chitosan application reduces the rate of pepper transpiration and increased water efficiency without reduction in total dry matter and yield [27]. Chitosan degradation occur amino compounds and has about 8.7% nitrogen [28, 29]. Chitosan considered a plant growth promoting [30]. Improve the plant resistance for cold stress and works to improve nitrogen

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metabolism by enhancing enzymes activity [31, 32]. Chitosan stimulate production of some secondary metabolism cause cell membrane saving from oxidative, stomata closing and thus reduce transpiration ratio [2]. Chitosan application enhanced the plant growth and development by increasing enzymes which activate nitrogen metabolism and transportation [23]. Mondal *et al*. [33] reported that chitosan is a growth stimulant such as gibberellic acid which improves plant growth and yield. Chitosan acts to balance the cells osmotic, and therefore the ability to absorb water nutrients and reduce free radicals accumulation by enhancing antioxidant and enzymes activities [34].

Potato is the fourth most important crop, important food crop, a cash crop, and grown all over the world. Potatoes consider a good source of carbohydrates, vitamins and minerals and introduced in many industries such as French fries, chips and starch [35].

Summer heat is expected to rise and may be not suitable for the growth and production of potatoes during summer season, while this agricultural season is essential for the tuber seeds production under Egypt conditions. Summer is characterized by high temperature and its impact on potato productivity and quality. Climatic change solutions must be devised to increase the cultivated area and increase production of potatoes. Although the plant has some compounds to adjust the osmotic pressure to cop stresses, it may be not insufficient, for that external treatment was done to increase the plant efficiency against the stress. Therefore, the objective of this study is to investigate the effect of exogenous application of proline and chitosan on growth and yield of potato plants under unfavorable condition of late planting (mid Feb.). For that potatoes were cultivated late to simulate the exposure potato plants to high temperature during growth and tubers production.

MATERIALS AND METHODS

Field experiment was carried out during two summer seasons 2016 and 2017 at the Experimental Station of the Faculty of Agriculture, Cairo University to investigate the effect of proline and chitosan as a foliar application on potato growth and yield under unfavorable condition of late planting in mid-February. The experimental units were arranged in a randomized complete block design (RCBD) with three replications. Each experimental unit was 10.5m^2 and consisted of five ridges, each 3m long and 0.7m wide. The experiment includes 6 treatments which were control (without spray), spray with tap water, proline (0.15, 0.2 g/l) and chitosan (0.25, 0.5g/l) as foliar application on potato cultivar Lady Rosetta. Mineral fertilization was the same for all treatments. Fertilization was applied at the following does: 180kg N in form ammonium sulfate (20.5%), 60kg P_2O_5 in form calcium superphosphate (15.5%) and 96 kg K_2O in form of potassium sulfate (48%). The calcium superphosphate was added as one does during the soil preparation. Nitrogen and potassium fertilization was divided into three equal batches the first does applied at preparing the soil, the second dose after four weeks of planting and the third after seven weeks from planting. Temperature recorded during the growing seasons and presented in Table 1. Potato Seeds were sown in 16th and 15th February in 2016 and 2017 seasons respectively. The foliar application, were applied after 45 days from planting and then repeated three times interval every 10 days. Potato seed tubers were planted in hells at 25cm between plants and tubers were harvested after 100 days from planting in both seasons. Plant height was measured at 60 days after planting, and total chlorophyll content at 60 days was measured as SPAD unit (SPAD - 502). At harvest the total yield of tubers as ton/fed., economic yield was calculated: Economic yield (EY) =yield of economic part of the plant [36]. Tubers chemical composition: TSS (measured by digital refractometer) dry matter percentage and specific gravity. Total nitrogen, potassium, phosphorus and starch percentage were determined according to the methods described in AOAC [37]. Protein percentage: it was calculated by multiplying the total nitrogen by the factor 6.25. The L.S.D. was used for testing the significance of means in the experiment according to Snedecor and Cochran [38].

Table 1: Average monthly temperature (°C) during growing seasons.

	Season 2016			Season 2017		
Month	Max	Min	Average	Max	Min	Average
February	22	12	16	19	9	13
March	25	13	19	23	12	17
April	31	17	24	27	15	21
May	32	19	25	32	19	25

Table 2: Effect of proline and chitosan as foliar application, on plant height, chlorophyll content and specific gravity of potato plants in late planting summer seasons of 2016 and 2017.

	Season 2016			Season 2017		
Treatments	Plant height (cm)	Chlorophyll (SPAD)	Specific gravity	Plant height (cm)	Chlorophyll (SPAD)	Specific gravity
Without spray	36.00 bc	48.15 a	1.076 a	38.30 b	45.96 b	1.075 a
Water spray	31.48 d	49.18 a	1.080 a	36.87 bc	45.53 b	1.083 a
Proline 0.15g/l	39.16 ab	48.75 a	1.076 a	40.98 a	44.65 b	1.073 a
Proline 0.2g/l	35.61 c	47.30 a	1.075 a	35.63 c	47.96 b	1.074 a
Chitosan 0.25g/l	39.83 a	44.80 a	1.076 a	41.10 a	52.16 a	1.076 a
Chitosan 0.5g/l	36.20 bc	46.40 a	1.073 a	38.30 b	44.96 b	1.073 a

In each column, values followed by the same letter(s) do not differ significantly at P=0.05 by LSD.

Table 3: Effect of proline and chitosan as foliar application, on total soluble solids (TSS), dry matter percentage and economic yield (EY) of potato tubers in late planting summer seasons of 2016 and 2017.

	Season 2016			Season 2017		
Treatments	TSS	Dry matter (%)	EY	TSS	Dry matter (%)	EY
Without spray	5.7 a	20.98 b	27.28 e	6.0 a	21.31 ab	51.15 c
Water spray	6.3 a	23.33 a	109.06 a	7.0 a	22.13 a	81.33 ab
Proline 0.15g/l	6.0 a	21.03 b	97.79 bc	5.9 a	19.32 c	62.29 bc
Proline 0.2g/l	5.6 a	23.11 a	104.09 ab	5.9 a	22.25 a	99.08 a
Chitosan 0.25g/l	5.8 a	20.41 b	89.31 c	5.7 a	20.26 bc	93.75 a
Chitosan 0.5g/l	6.1 a	21.32 b	73.57 d	6.1 a	21.12 ab	86.03 a

In each column, values followed by the same letter(s) do not differ significantly at P=0.05 by LSD.

RESULTS AND DISCUSSION

Plant Height, Chlorophyll Content and Specific Gravity: Data presented in Table 2 showed that there were no significant differences between treatments in specific gravity in both seasons and chlorophyll content in the first season. Meanwhile, there are a slight significant in the second season whereas, foliar application of chitosan at 0.25g/l had the highest chlorophyll content in the leaves but other treatments showed the similar significant. El-Miniawy *et al*. [39] reported that Strawberry plants response to chitosan application and increased all vegetative growth characteristics, but no significant effect on chlorophyll content. Potato plants treated by proline at 0.15g/l as foliar application or chitosan at 0.25g/l recorded the highest plant height in both seasons. While, plants treated by proline at 0.2g/l recorded the lowest plant height. Our result in agreement with Kahlaoui *et al*. [21] who concluded that high concentration of exogenous proline (20mg/l) may be harmful and reduced plant growth. Santos *et al*. [40] reported that proline consider a source of nitrogen to improve plant growth. Applied of chitosan was improved plant height on strawberry [41]. Application maize plants with chitosan at 100 or 125ppm were enhanced plant height [42]. On contrast Khan *et al*. [43] indicated that chitosan application did not improved plant growth plant height of maize and soybean.

Total Soluble Solids (TSS), Dry Matter Percentage and Economic Yield (EY): Data presented in Table 3 showed that there were no significant differences between treatments in TSS in both seasons. Potato plants treated by proline at 0.2g/l as foliar application or treated by water only gave the maximum tuber dry matter percentage in both seasons and the maximum EY in the first season. Beside, plants were treated by chitosan at 0.25 or 0.5g/l as a foliar application had the similar significant in EY in the second season. All treatments were superior to control in EY. El-Miniawy *et al*. [39] reported that Strawberry plants response to chitosan application and increased dry weight and yield but no significant effect on T.S.S content. Spraying Indian Spinach (*Basella alba* L.) with chitosan by 75ppm gave the maximum economic yield [33]. Application maize and okra plants by chitosan 100 or 125ppm were enhanced growth and yield parameter (total dry matter and biological yield) [42, 44]. Spraying *Vicia faba* by proline improved the growth and dry matter [45]. On the contrary Khan *et al*. [43] suggested that chitosan application did not improve shoot dry weight of maize and soybean.

Protein, Starch Percentage and Tuber Yield: Data presented in Table 4 showed that there were significant differences between treatments in tuber protein, starch percentage and tuber yield in both seasons. All treatments were superior to control in tuber protein

Table 4: Effect of proline and chitosan as foliar application, on protein, starch percentage and yield of potato tubers in late planting summer seasons of 2016 and 2017.

	Season 2016			Season 2017		
Treatments	Protein (%)	Starch (%)	Yield (ton/fed.)	Protein (%)	Starch (%)	Yield (ton/fed.)
Without spray	6.75 e	14.70 b	2.973 c	6.70 e	14.99 ab	5.638 c
Water spray	7.06 c	16.79 a	10.086 a	7.02 c	15.72 a	8.396 ab
Proline 0.15g/l	8.06 a	14.74 b	10.623 a	8.03 a	13.22 c	7.353 bc
Proline 0.2g/l	6.94 d	16.59 a	10.286 a	6.92 d	15.83 a	10.203 a
Chitosan 0.25g/l	7.06 c	14.19 b	9.996 a	7.02 c	14.06 bc	10.046 a
Chitosan 0.5g/l	7.56 b	16.00 b	7.886 b	7.52 b	14.82 ab	9.296 ab

In each column, values followed by the same letter(s) do not differ significantly at P=0.05 by LSD.

Table 5: Effect of proline and chitosan as foliar application, on nitrogen, phosphorus and potassium percentage of potato tubers in late planting summer seasons of 2016 and 2017

	Season 2016			Season 2017		
Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Without spray	1.08 e	0.19 a	2.17 e	1.04 e	0.18 a	2.15 e
Water spray	1.13 c	0.16 b	2.56 d	1.12 c	0.15 b	2.54 d
Proline 0.15g/l	1.29 a	0.20 a	2.70 a	1.27 a	0.18 a	2.69 a
Proline 0.2g/l	1.11 d	0.20 a	2.70 a	1.09 d	0.18 a	2.69 a
Chitosan 0.25g/l	1.13 c	0.13 c	2.59 c	1.11 c	0.12 c	2.57 c
Chitosan 0.5g/l	1.21 b	0.13 c	2.67 b	1.18 b	0.12 c	2.66 b

In each column, values followed by the same letter(s) do not differ significantly at P=0.05 by LSD.

percentage. It was clearly noticed that the maximum tuber protein percentage were recorded in plants treated by proline at 0.15g/l followed by plants treated by chitosan at 0.5g/l. Potato plants treated by proline at 0.2g/l as foliar application or treated by water only had the highest tuber starch in both seasons. All treatments were superior to control in tuber yield in both seasons. Plants treated with proline at 0.15or 0.2g/l, chitosan at 0.25g/l and plants treated by water only had the maximum tuber yield in the first season. Whereas, plants treated with proline 0.2g/l, chitosan at 0.25 or 0.5g/l and plants treated by water only had the highest tuber yield in the second season. Ashraf *et al*., [46] reported that yield reduction may be reached about 40% by exposing to high temperature. Kahlaoui *et al*. [21] reported that spraying proline under stress condition improves tomato growth and productivity under commercial production. Chitosan concentration, time of treatment and the plant age all that factors affect the success of the chitosan treatment [23]. Applied of chitosan increases strawberry yield [41]. Chitosan considered a plant growth promoting effects, resulting in increasing the yield of minituber production in tissue culture [30]. Abu-Muriefah [24] suggested that chitosan (200ppm) is a promising substrate to avoid the effect of drought and enhanced the growth and yield of *Phaseolus vulgaris*. El-Miniawy *et al*. [39] reported that the foliar application of chitosan increases Strawberry yield. The positive effect of chitosan in enhancing yield may be related in improving the nitrogen transportation which increased the vegetative growth [23]. Mondal *et al*. [42] indicated that by increasing chitosan concentration to 50mg/l showed increasing in growth parameters and total yield of Mungbean (*Vigna radiate*) plants but higher that concentration may be toxic.

N, P and K Content: Data presented in Table 5 showed that there were significant differences between treatments in tuber nitrogen, phosphorus and potassium percentage in both seasons. All treatments were superior to control in tuber nitrogen and potassium percentage. It was clearly noticed that the maximum tuber nitrogen percentage were recorded in plants treated by proline 0.15g/l followed by plants treated by chitosan at 0.5g/l. potato plants treated by proline at 0.15 or 0.2g/l as a foliar application recorded the maximum tuber content of phosphorus and potassium followed by potato plants treated by chitosan at 0.5g/l in both seasons but potato plants untreated (control) recorded the similar significant in tuber phosphorus content in both seasons. Spraying *Vicia faba* by proline improved K uptake [45]. Ali *et al*. [47] reported that spraying maize by proline enhanced N, P, K content under drought stress. Proline plays an important role in cell osmotic adjustment, allowing the plant to absorb nutrients [19]. Spraying cucumber plants under saline stress conditions with proline improved the leaves minerals content (N, P and K) compared to the unsprayed plants

[48]. On the other hand Abdel-Mawgoud *et al*. [41] concluded that chitosan foliar application on strawberry increased the leaves content of N and K but no significant effect on P content.

CONCLUSION

Despite the superiority of the foliar application of proline and chitosan on improvement effect of potato growth. It is clear that the potato plants have the ability to produce the secondary compounds that necessary to reduce the harmful effect of the stress (heat stress).

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