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STIMULATE THE ABILITY OF POTATO PLANT TO TOLERANCE LOW TEMPERATURE IN WINTER PLANTATION

Ahmed M. EL-Anany
Potato and Vegetatively Propagated Vegetables Dep., Hort. Res., Inst., A.R.C., Egypt

ABSTRACT

This research was conducted during two baffling agricultural seasons of 2016/2017 and 2017/2018 at Kaha Vegetables Research Farm, Hort. Research Institute., Agriculture Research Center, Egypt to study the stimulation of the potato plant's cv. Picasso ability to tolerance low temperature and improving tubers yield and qualities through appropriate agricultural practices in parallel with the addition of adequate fertilizers of NPK plus micro-nutrients spraying and some anti-stress substances. The experiment included eight treatments consisting of two fertilization treatments in main plots and four anti-stress as sub plots.

The results indicate that *treating plants with a suggested nutrients program, along with foliar spraying with some minor elements and some anti-stress, such as selenium plus vitamin C or vitamin E in addition to a commercial anti-stress compound led to stimulating the plant's ability to tolerance low temperature and improved plant growth.*

Anti-stress commercial compound at 100 ppm concentration exhibited the significant superiority in most of vegetative growth traits (stem length - average number of both stems and leaves as well as fresh weight of stems and leaves and reflected so positively on the total yield of tubers, quality characteristics and the percentage of tubers starch. Also, results indicate that the remainder of the treatments recorded significant differences and gave values that reached the level of significance in most of the characteristics of vegetative growth and yield and its components, compared to the control treatment, which recorded the lowest values of all studied traits.

Conclusively, *the recommended program for planting in the off-season growing cycles will give the highest yield due to the balanced fertilization and anti-stress /anti-oxidants, as well as, in the same time will take care of the tubers quality. So that, the tubers yield will gain the* *highest values of economic competition in locally and international markets and to contribute as a good source of hard currency for Egypt.*

Key words: *Potato (solanum tuberosum) , tubers, nutrients, anti-oxidants, anti-stress, low temperature , growth and yield.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important and strategic vegetable crops in Egypt and ranks fourth in the world after rice, wheat and Maize (Ewing, 1997).Their tubers is a rich source of carbohydrates and provide other nutrients such as vitamins, minerals, proteins, fats, antioxidants, and others (Bach *et al*., 2012). Potato is grown in three seasons for local consumption in Egypt and export into many countries. The plants of Potato need a moderate climate in order to grow better vegetative, but the crop needs a cold climate, not frost (Hijmans, 2003) where the frost, in Egypt, is the biggest problem at late plantings of the autumnal season and offseason growing cycles, specially the boggling agricultural seasons, which intended for export to other countries. There are many studies confirming that the vegetative growth phase of the potato plant is faster in temperatures ranging from 20-25˚C,whereas the optimal range for tuberization is 15–20°C (Rykaczewska, 2015).The optimum temperature for canopy photosynthesis is 24°C early in the growth period and shifts to lower temperatures as the plants aged and the total end-of-season biomass is highest in the 20°C treatment. Potato is also frost sensitive, and severe damage may occur (Hijmans *et al*. 2003) with reducing the rate of metabolism exposure of plants to the frost leads to the wilting of new buds and leaves as a result of the freezing the water then thawing and turning the green tissues to brown, then black (Sakai and Larcher, 1987).Frost harms the roots of plants resulting in destruction of the root hairs, which absorb water and minerals, and therefore the plant takes longer to restructure and grow these hairs, and this is at the expense of productivity (Man *et al*., 2009). Therefore, it was necessary to search for agricultural practices that provide protection from the frost conditions that the plants are exposed to during these harsh periods and are inexpensive for the farmers. The mitigation of abiotic stress, recently, has become effective by exogenous application of protectants in the form of trace elements (selenium, silicon, *etc*.) and nutrients (micro and macronutrients) as Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Fe, Zn, Mn ... *etc*. (Hasanuzzaman *et al*., 2013).

Ascorbic acid (Vitamin C) is an important antioxidant in plants, which accumulates in plants as an adaptive mechanism to environmental stress such as low temperature. Ascorbic acid regulates stress response as a result of a complex sequence of biochemical reactions such as activation or suppression of key enzymatic reactions, induction of stress responsive proteins synthesis, and the production of various chemical defense compounds and it had a protective role in plant cells from the adverse effects of low temperature (Khan *et al*. 2011).

Vitamin E is thought to protect chloroplast membranes from photo-oxidation and to help provide an optimal environment for photosynthetic machinery, adding that accumulations of vitamin E often occur in response to a number of biotic stresses, including high light, drought, salt and cold, and may provide additional protection against oxidative damage (Bosch, 1995).

Selenium promote growth and development and increase resistance and antioxidant capacity of plants exposed to abiotic stressful environment, such as drought, salt, ultraviolet, and cold stresses (Chu *et al*., 2010).

Also, it has been found that anti-stress treatment containing amino acids is involved in the synthesis of proteins which participate in stabilizing the membranes against the injury caused by the oxidative damage due to the frost (Epand *et al*., 1995).Numerous studies indicate the positive role that nutrients play in relieving the various pressures on plants that resulted from adverse environmental conditions where Waraich *et al*., (2011) found that the availability of nitrogen in the plant's environment reduces the harmful effects of environmental stress. Likewise, it has been found that the balanced fertilization with major elements has a positive role in increasing growth and yield and increasing plant tolerance to environmental conditions. Potassium has a major role in controlling the activity of enzymes, cations and anions, cell expansion, it regulates the movement of stomata increasing plant resistance to diseases and frost and positively affecting potato crop production through transporting and storing starchy materials in tubers (Singh *et al*., 2014).Also, phosphorous has a major role in the transfer of cellular energy and it is a component of nucleic acids and is involved in many coenzymes and phospholipids which is enters in the composition of cell membranes that resist the cold process in plants (Rosen *et al*., 2014). It is known that calcium is necessary in building cell walls and essential for the stability of membranes, as it link between phosphate and carboxyl groups on the surface of the membrane(Subramanian *et al*., 2011). It must be mentioned that magnesium is the forgotten element in crop production (Cakmak and Yazici 2010) that serves along with potassium as a cation in similar physiological processes, such as in the regulation of the cation–anion balance and as an osmotically active ion in the turgor regulation of cells (Marschner, 2011). Moreover, the role of boron element in the composition of cell walls and sugar transport, cell division, cell development, the synthesis of amino acids and proteins, and the regulation of carbohydrate metabolism as well as improves calcium absorption and stability in the cell walls. It works to increase the size of tubers and increase the yield (Saif El-Deen, 2005 and Singh and Kathayat,2018).

Therefore, this work aims to know the effect of using good and balanced nutrition of macro and micro elements and foliar spray with some anti-stress substances on potato plants' tolerance low temperature in winter plantation and its effect on growth, yield and tubers quality.

MATERIALS AND METHODS

The present investigation was carried out during the two successive winter seasons of 2016/2017 and 2017/2018 at Kaha Vegetables Research Farm, Hort. Res. Inst., Agric. Res. Center, Egypt to study the effect of mixture of macro- and micronutrients along with some anti-stress (based on their protective activity which is related to their antioxidant properties, efficiently scavenging singlet molecular oxygen and peroxyl radicals as shown in Table (1) on the morphological and metabolical performance of potato (*Solanum tuberosum* L.) cv. Picasso towards alleviation the adverse effects of low temperature stress and its corresponding oxidative one, improving its tuber yield and quality during early cold season.

Soil samples analyses were carried out according to the procedures described by Jackson (1973) and resulting in physical properties as organic matter (0.98%)and textural class (Clay loam) as well as chemical properties as pH (7.7), electric conductivity E.C. (0.62 ds/m) and available nutrients (mg/kg soil) as macro elements [N(60.6 and 58.3),P (8.1 and 7.9) and K (189.2 and 190.5)] as well as micro-elements [Zn (0.39 and 0.48), Mn (1.41 and 2.20) and Fe (1.09 and 1.13)] during the first and second seasons, respectively. Local meteorological data at the experimental region during first and second seasons were given in Figure (1).

The present experiment included eight treatments, which were the combinations of two fertilization treatments , and three ant-stress as foliar spray beside untreated sprayed with distilled water). These treatments were arranged in a split plot in a complete randomized block design, fertilization treatments were arranged in the main plots and the anti-stress were randomly arranged in the sub plots, as follow:

a. Main plots (fertilization treatments):

1. **Control** (CAP): NPK rates (180, 75 and 96 kg N,Pand K/fed. respectively) according to common agricultural practice (CAP) .
2. **New nutrients program**: extra-supply of minerals application (E-SM) 200 kg N/fed. as ammonium sulfate and ammonium nitrate equally(100 kg N/fed. from each source), 83 Kg P_2O_5/fed. and 107 kg K_2O/fed. in

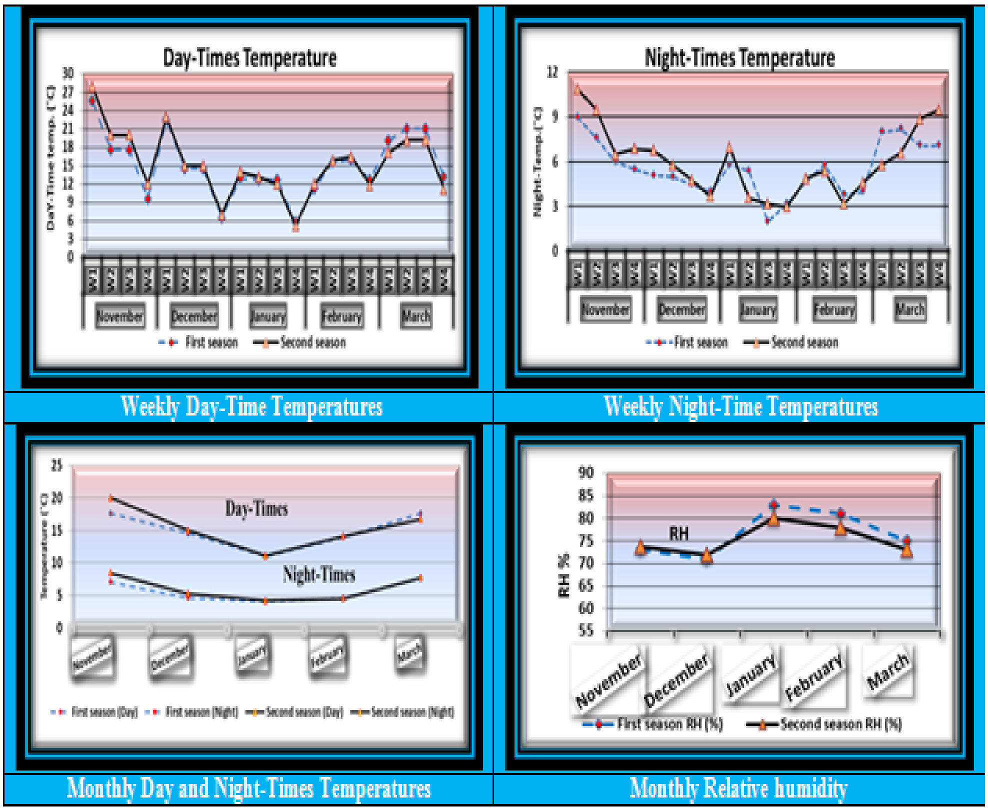

Figure1: Average of weekly (upper) and monthly (below) temperatures (˚C) as well as relative humidity during the 1st and 2nd seasons .

addition, 17 kg/fed Ca (calcium nitrate, 17% Ca) and 10 kg/fed. Mg (magnesium sulfate, 10% Mg). As for the microelements, the mixture of chelated Fe, Zn and Mn (1:1:1) was supplied as a foliar application in 150 ppm concentrations of each at 45, 60 and 75 days after planting (400 L solutions of each /fed.)

b. Sub-plots (Anti-stress treatments):

1. Control (spraying with water).

2. A_1: V C (Vitamin C, 150 ppm) in combination with Se (selenium, 50ppm).

3. A_2: V E (Vitamin E, 250 ppm) in combination with Se (selenium, 50ppm).

4. A_3: Anti-stress (commercial compound) at a concentration of 100 ppm.

All anti-stress treatments were sprayed four times at 40, 55, 70 and 85 days after planting in both growing seasons.

Table 1. Name, descriptions and sources of anti-stress

Name	Description	Notes and sources
Vitamin (C)	Ascorbic acid: an odorless, pleasant taste, white to slightly yellowish, powdered solid; soluble in cold water	Technogene group, Soliman Gohar Square, Dokki, Giza, Egypt.
Vitamin (E)	Alpha-tocopherol: an odorless, tasteless, light yellow, oily liquid or viscous liquid	This fat-soluble vitamin has been used in large doses as an antioxidant, Technogene group, Dokki, Giza, Egypt
Selenium	An odorless, solid metallic powder, non-toxic material	Selected based on its beneficial effect on growth and stress tolerance of plants by enhancing their antioxidative capacity (Djanaguiraman *et al*. 2005 and Hasanuzzaman *et al*., 2013)
Anti-Stress	A commercial compound contains: Acrylic organic (10%), Polypeptideenzymes (20%), Ingredients (29%) , Amino acids enzymes (20%), Protein enzymes (20%),vitamin A, vitamin D_3 and vitamin K_3	Technogene group, Dokki, Giza, Egypt

The sub plot experimental unit area was 12 m^2 containing four ridges with 4m length and 0.75 m apart. The seeds of potato were planted on 15th November at 20 cm in between in both seasons. One ridge was used to measure the morphological and chemical traits and the other three ridges were left for yield determinations. In addition, two ridges were left as a buffer zone between each two experimental units to avoid lateral seepage of spraying materials. Name, descriptions and sources of anti-stress are shown in Table 1

All the treatments were fertilized with the common agricultural rates of NPK, *i.e.*, 180 kg N/fed as ammonium nitrate (33.5% N) was added at four equal doses, the first one applied in planting date and repeated every 3 weeks until 85 days after planting dates, 75 kg P_2O_5/fed. as calcium superphosphate (15.5% P_2O_5), calcium nitrate at 17 kg /fed., magnesium sulphate at 10 kg /fed. were added once before planting and 96 kg K_2O/fed. as potassium sulphate (48% K_2O) as a source of potassium was added in five constant doses (20% for each), starting on the first irrigation and terminated on 2-weeks before harvesting date. The other cultural practices were applied according to the instructions laid down by the Ministry of Agriculture, Egypt.

Data recorded:

1- *Growth parameters:*

A random sample of five potato plants were randomly taken from each plot at 90 days after planting date to estimate the plant stem length (cm), number of main stems/plant, number of leaves/plant, fresh and dry weight/plant of both leaves and stems (g) as well as leaves area/ plant (cm^2).

2- *Yield and its components:*

At harvest time (120 days after planting), yield of each plot were counted and weighed in g (fresh weight of tubers, g /plant) and converted to obtain total yield (ton/fed.), marketable yield of tubers (ton/fed.) and number of tubers/plant.

3- *Tuber quality:*

Chemical quality analyses were determined based on dry matter, N, P and K contents. The tuber samples (DM) were digested using a concentrated sulfuric and perchloric acids mixture, as described by **Chapman and Pratt (1982)**, and then N was determined using a microkjeldahl method. Thereafter, the extract was used to measure the total contents of K, and P using a flame photometer device and the colorimetric method, respectively.

Dry matter (%) and starch content of tubers were determined according to **A.O.A.C. (1990)** and specific gravity (%) was determined according to the equation of Murphy and Goven (1959) as follow:

$$\textit{Specific gravity} = \frac{\textit{Weight in air}}{\textit{Weight in air} - \textit{Weight in water}}$$

The total protein content was calculated by multiplying the nitrogen % in tuber with the conversion factor of 6.25 (Ranganna, 1977).

***Statistical analysis*:**

Data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1989) and means were compared using L.S.D at 5%.

RESULTS AND DISCUSSION

Two seasons applied experiments were conducted under cold stress to study and evaluate the probability of some anti-stress (Se in combination with vitamin C or vitamin E and a commercial anti-stress compound alone) and their role in mitigating the adverse effect of stress on potato plants in

Northern Egypt region. It seems very likely that, in the present work, the effect of stress on the potato crop restricted to exposure of the effect of cold weather (due to cultivation in later than the recommended date). Therefore, the control plants of main plot (CAP treatment), which received only recommended NPK fertilizer was not protected against cold temperature stress and its adverse effects. Thus, the results of CAP treatment are considered as cold stress data.

1. *Effect of nutrients program:*

Changes value in vegetative growth traits (stem length, number of stems and leaves, fresh and dry weight of leaves, stems/ plant, leaves area/ plant, tubers number/plant, tubers weight/plant total and marketable yield, chemical and constituents traits in tuber as affected by new nutrients program on the potato plants grown under low temperature stress condition (winter season) are presented in Tables (2, 3 and 4).

The results indicated that significantly highest values of fertilizing by E-SM mixture of the new NPK fertilizer application plus Ca, Mg and spraying with Fe, Mn and Zn were recorded in all studied traits in both seasons except number of stems and leaves (Table 2) in 1st season, both starch and phosphorus contents (Table 3) in 2nd one and specific gravity (Table 4) in both seasons comparing with control (CAP).

Table 2. Changes values in vegetative traits as affected by new nutrients program at 90 days from planting of potato plants grown in winter plantation, during 2016/2017 and 2017/2018 seasons

Treatments	Stem length (cm)	Number		Fresh weight (g)		Dry weight (g)		Leaves area/ plant (cm^2)
		stems	leaves	Leaves	Stems	leaves	Stems	
	2016/2017							
CAP	42.93	2.97	70.05	231.14	109.52	18.30	11.37	3742.9
E-SM	52.43	3.59	81.29	277.20	117.13	21.39	13.93	4654.3
LSD at 0.05 level	3.67	NS	7.59	6.85	6.98	2.844	1.53	270.8
	2017/2018							
CAP	41.98	3.02	70.31	235.81	110.58	17.87	12.48	3452.1
E-SM	51.70	3.94	82.85	278.75	118.1	22.53	16.02	4334.2
LSD at 0.05 level	6.62	0.90	4.47	13.60	5.93	1.91	0.78	223.4

CAP: control (Common agricultural practice of NPK) **E-SM**: extra-supply minerals application

Data also, show that treated plants with the new nutrients program exhibited a high increment in all vegetative growth traits, *i.e.*, stem length, stems number, stems dry weight, leaves area/ plant, leaves dry weight,

Table 3. Changes values in yield and its components as affected by new nutrients program at harvesting time on potato plants grown in winter plantation, during 2016/2017 and 2017/2018 seasons

Treatments	Tubers number /plant	Tubers weight (g/plant)	Marketable Yield (ton/fed.)	Total Yield (ton /fed.)
2016/2017 season				
CAP	9.69	533.68	11.19	12.59
E-SM	10.68	639.66	14.44	15.47
LSD at 0.05 level	0.39	34.57	**0.52**	**0.92**
2017/2018 season				
CAP	9.63	546.41	11.79	13.45
E-SM	10.27	628.29	15.03	16.00
LSD at 0.05 level	0.61	44.80	**0.78**	**0.600**

CAP: control (Common agricultural practice of NPK) **E-SM**: extra-supply minerals application

Table 4. Changes values in tuber quality traits as affected by new nutrients program at harvesting time on potato plants grown in winter plantation during 2016/2017 and 2017/2018 seasons

Treatments	Dry matter (%)	Starch %	Specific gravity (g/cm^3)	N (%)	P (%)	K (%)	Protein (%)
	2016/2017 season						
CAP	18.92	10.22	1.06	2.84	0.34	3.50	17.71
E-SM	20.34	11.5	1.06	3.09	0.36	3.55	19.34
LSD at 0.05 level	**0.69**	**0.59**	**NS**	**0.09**	**0.02**	**0.02**	**0.75**
	2017/2018 season						
CAP	18.92	10.56	1.05	2.76	0.33	3.38	17.24
E-SM	20.34	11.36	1.07	3.14	0.36	3.63	19.63
LSD at 0.05 level	**0.98**	**NS**	**NS**	**0.10**	**NS**	**0.08**	**0.63**

CAP: control (Common agricultural practice of NPK) **E-SM**: extra-supply minerals application

They mentioned that the nutritional status of plants greatly affects their ability to adapt to adverse environmental conditions, and that nitrogen plays a major role in the use of absorbed light energy and the elements can play a good role in increasing the yield of potato tubers, as nitrogen has a greatest impact on potato yield formation among all basic macronutrients, also potassium element plays many roles in many physiological processes within the potato plant, in addition to the large cycle in transporting and storing metabolites to tubers and increased plant resistance to environmental stresses (Waraich *et al*., 2011). Also our results are in line with Hakerlerler *et al.* (1997) who stated that the calcium element plays an important role in revitalizing the plant during the cold, enhances the growth of the plant under conditions of low temperature stress; it works on plant adaptation to cold stress and to recover from injury by activating plasma membrane enzymes. Regarding the increase in vegetative growth, it could be attributed to the positive role of micronutrients in enhancing Photosynthesis and biosynthesis of proteins to protect cells and the transformation of photosynthesis products in the form of carbohydrates they are stored in the tubers (Mohamadi, 2000). Also, micro-elements activate the plant to absorb the macro-elements, which leads to an increase in the metabolism and an increase in the content of elements in the plant as the microelements stimulated the uptake (Tripathi *et al.*, 2015). In this regard, El-Sayed *et al*. (2007) mentioned that spraying with zinc, manganese, and iron led to the stimulation of growth and cell division and development, regulation of carbohydrate metabolism, and improvement of the characteristics of vegetative growth, yield, its components.

2. *Effect of anti-stress as foliar spray*

Data presented in above Tables (5, 6 and 7) show the effect of foliar applications, *i.e.*, 3-stressors treatments on vegetative growth parameters, yield and its components as well as quality of potato tubers in terms of elemental analysis and protein traits. It is clearly illustrated that all anti-stress foliar applications significantly increased number of leaves/plant, leaves fresh weight, leaf area and marketable tuber yield as well as each of nitrogen, phosphorus, potassium and protein contents in both seasons and dry weight of both leaves and stems in 1st season as well as each of number of tubers/plant, tuber dry matter and starch content in 2nd one compared with the control.

The results showed that, increase in growth rate such as stem length (cm), number of stems and leaves, fresh and dry weight of leaves and stems (g) as well as leaf area (cm^2), yield and its components, *i.e.,* tubers number/plant, tubers weight (g/plant), total yield (ton/fed.), marketable yield (ton/fed.), tubers dry matter (%), starch (%) and specific gravity (g/cm^3) as well as quality of potato tubers in terms of elemental analysis and protein (comparing to distilled water) was obtained as a result of most different treatments in this study. Treated plants with the different anti-stressors showed that 100 ppm of A_3 exhibited a high significant increment in most studied traits in both seasons, *i.e*., stem length, number of stems, number of leaves, leaves fresh weight, stems fresh weight, leaf area, total yield per fed., marketable yield /fed., specific

Table 5. Changes values in vegetative traits as well as both number and weight of tubers/plant as affected by anti-stress foliar spray at 90 days from planting of potato plants grown in winter plantation during 2016/2017 and 2017/2018 seasons

Treatments	Stem length (cm)	Number/plant		Fresh weight (g)		Dry weight (g)		Leaves area/ plant (cm^2)
		Stems	leaves	Leaves	Stems	leaves	Stems	
2016/2017 season								
Water	44.86	2.99	70.88	239.5	110.6	18.59	10.87	3878.7
A_1	49.25	3.38	77.22	251.3	113.4	20.08	12.83	4192.3
A_2	46.71	3.29	75.75	256.9	113.9	20.46	13.50	4298.9
A_3	49.89	3.44	78.81	269.0	115.4	20.25	13.41	4424.4
LSD	3.56	0.34	1.77	7.33	4.2	1.12	1.30	145.72
2017/2018 season								
Water	44.18	3.05	74.00	245.8	111.5	19.01	13.34	3617.2
A_1	47.17	3.6	75.43	254.5	113.9	20.61	14.36	3984.1
A_2	45.81	3.55	77.83	256.8	115.6	19.97	14.39	3933.3
A_3	50.2	3.72	79.07	272.0	116.3	21.22	14.91	4038.1
LSD	3.17	0.54	2.65	7.84	4.74	1.19	1.13	126.58

A_1: vitamin C + Se **A_2**: vitamin E + Se **A_3**: commercial Anti-stress

Table 6. Changes values in yield and its components traits as affected by anti-stress foliar spray at harvesting time of potato plants grown in winter plantation, during 2016/2017 and 2017/2018 seasons

Treatments	Tubers number /plant	Tubers weight (g/plant)	Marketable yield (ton/fed.)	Total yield (ton/fed.)
2016/2017 season				
Water	9.87	567.3	11.92	13.48
A_1	10.34	586.7	13.10	14.27
A_2	10.25	576.9	12.84	13.95
A_3	10.29	615.8	13.39	14.40
LSD at 0.05 level	0.39	13.49	0.351	0.72
2017/2018 season				
Water	9.60	559.6	12.59	14.13
A_1	10.12	605.9	13.92	15.01
A_2	9.90	581.2	13.21	14.45
A_3	10.16	602.7	13.92	15.30
LSD at 0.05 level	0.14	23.3	0.42	0.74

A_1: vitamin C + Se **A_2**: vitamin E + Se **A_3**: commercial Anti-stress

Table 7. Changes values in tuber quality traits as affected by anti-stress foliar spray at harvesting time of potato plants grown in winter plantation during 2016/2017 and 2017/2018 seasons

Treatments	Dry matter (%)	Starch %	Specific gravity (g/cm^3)	N (%)	P (%)	K (%)	Protein (%)
	2016/2017 season						
Water	19.26	10.528	1.056	2.85	0.34	3.35	17.79
A_1	19.43	10.678	1.060	3.01	0.35	3.43	18.83
A_2	19.82	11.032	1.060	2.99	0.35	3.5	18.81
A_3	20.01	11.217	1.063	2.99	0.35	3.51	18.69
LSD	0.46	0.41	0.005	0.07	0.01	0.03	0.44
	2017/2018 season						
Water	19.06	10.238	1.056	2.85	0.33	3.44	17.79
A_1	20.07	11.133	1.060	3.00	0.34	3.48	18.72
A_2	20.31	11.29	1.060	3.00	0.35	3.52	18.77
A_3	20.28	11.168	1.065	2.96	0.35	3.59	18.5
LSD	0.81	0.847	0.008	0.05	0.01	0.03	0.32

A_1: V$_i$C + Se **A_2**: V$_i$E + Se **A_3**: commercial Anti-stress

gravity and potassium content in tubers by 11.2%, 15.1%, 11.2%, 12.4%, 4.4%, 14.1%, 6.8%, 12.3%, 0.7% and 4.6% at 1st season and 13.6%, 22.0%, 6.9%, 10.7%, 4.3% 11.6%, 8.3%, 10.6%, 0.9% and 4.2% at 2nd season, respectively, over the corresponding untreated plants (control) followed by A_1 in stem length, number of stems per plant, total yield per fed., marketable yield /fed. and specific gravity in both seasons as well as number of leaves and leaves area/ plant in 1st and 2nd seasons, respectively.

However, it was distinct that A_2 (vitamin E + Se) treatment showed significantly the highest value in dry weight of both leaves and stems at the 1st season as well as tubers dry matter and starch contents at the 2nd one, followed by A_3 (commercial Anti-stress) then A_1 (vitamin C + Se), with no significance differences between them and reverse trend for the effects on leaves area/ plant , tubers dry matter, starch content and specific gravity in the first season. Generally, no significant differences were observed among the three studied anti-stressors in number of stem, stems fresh weight, dry weight of stems, specific gravity, nitrogen content and protein percentage at both seasons as well as each of stem length, number of leaves, leaves dry weight, tubers number, total yield/fed. and phosphorus content of tubers in 1st season and each of leaves area/ plant, tuber dry matter and starch content in 2nd one. It is known that frost impacts directly on potato productivity (Hijmans *et al*., 2003).

Therefore, the control plants showed significantly the lowest values for all the studied traits, this is, to far extent, proved that these plants were greatly affected in severe and harmful way by the prevailing low temperature (Figure

1) and its probable inducible oxidative stress (Erickson and Markhart, 2002). Moreover, it was markedly observed from data that these yield increments, as affected by the applied treatments, were greatly associated with their similar enhance able effect on number of tubers. The internal physiological disturbances and the accompanied agronomical depression of low temperature affected control plants were greatly ceased by all the applied antioxidant treatments, which succeed in alleviating the deleterious effects of cold stress, due to their antioxidant roles in quench formed reactive oxygen radicals or activating enzymes related with scavenging and removing the toxic and degradable ROS away from the center of the active metabolic machinery of plant tissues i.e. peroxidase, superoxide dismutase and catalase (Schneider, 2005). Moreover, the active roles of vitamin C, vitamin E, selenium and anti-stress which act as antioxidants that protect the cell from oxidative processes that are due to environmental stress impede the growth process and affect the yield. Havaux *et al*. (2005) indicated that foliar spraying with compounds containing amino acids works to protect the plasma membranes from damage to environmental stresses. Our results were coincided with those of Fathy *et al*., 2003 (vitamin C or vitamin E+selenium); Fathy and Khedr, 2005 (vitamin E+selenium), Hala *et al*., 2005 (vitamin E or vitamin C) and El-Seifi *et al*., 2009 (vitamin E+selenium, vitamin C, Zn and Ca). They stated that, the beneficial effects of the applied treatments (vitamin E+selenium, vitamin C, Zn and Ca) individually or paired may be also explained due to their functional roles in addition to Ca role, since it is tightly related with membrane stability and integrity, structure of cell walls, signal transduction system, cell division and formation, involved in nitrogen metabolism (Marschner, 1995). As for the role of selenium, Djanaguiraman *et al.* (2005) stated that the selenium element individually, acte as antioxidant by inhibiting lipid peroxidation and per cent injury of cell membrane resulting in an increase in superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) enzymes activity that constitute the first line of defense against reactive oxygen species (ROS) and one of the most effective components of the antioxidant defense system in plant cells against ROS toxicity (Berwal and Ram, 2018).

3. *Effect of interaction treatments*

Tables 8 , 9 and Figure 2 show the abovementioned studied traits of potato plants sprayed with different anti-stressors with two nutrient programs (common NPK rates and extra-supply of minerals application) under cold stress. It is clearly noted that all anti-stressors treatments combined with the new nutrient program (E-SM) gave statistically equivalent or increase values in all vegetative growth traits as compared to the corresponding common

Table 8. Vegetative growth traits as affected by interaction between new nutrients program and anti-stress foliar spray at 90 days after planting on potato plants grown in winter plantation during 2016/2017 and 2017/2018 seasons

Treatments		Stem length (cm)	Number		Fresh weight (g)		Dry weight (g)		Leaves area/ plant (cm^2
			Stems	Leaves	Leaves	Stems	Leaves	Stems	
2016/2017									
CAP	Water	40.3	2.8	65.9	220.4	106.5	17.1	10.2	3340
	A_1	45.2	3.0	71.3	224.5	109.6	18.6	11.5	3734
	A_2	40.9	3.1	70.4	234.9	111.4	19.2	12.4	3843
	A_3	45.2	3.0	72.6	244.8	110.6	18.3	11.4	4054
ESM	Water	49.4	3.2	75.9	258.5	114.6	20.1	11.5	4417
	A_1	53.3	3.8	83.1	278.0	117.2	21.5	14.2	4651
	A_2	52.5	3.5	81.1	278.9	116.4	21.7	14.6	4754
	A_3	54.6	3.9	85.1	293.3	120.3	22.2	15.5	4795
LSD at 0.05 level		5.0	0.5	7.7	10.4	5.9	1.6	1.8	206
2017/2018									
CAP	Water	41.2	2.4	67.7	226.6	107.4	16.7	11.3	3085
	A_1	42.2	3.1	70.2	240.6	109.5	18.3	12.9	3616
	A_2	40.2	3.4	72.4	236.7	113.9	17.3	12.5	3461
	A_3	44.2	3.1	71.0	239.4	111.5	19.3	13.3	3646
ESM	Water	47.1	3.7	80.3	265	115.8	21.4	15.4	4149
	A_1	52.1	4.1	80.7	268.4	118.2	22.9	15.8	4460
	A_2	51.4	3.7	83.3	277	117.3	22.7	16.3	4406
	A_3	56.2	4.3	87.2	304.6	121.1	23.2	16.6	4322
LSD at 0.05 level		4.5	0.8	5.2	11.1	6.7	1.7	1.6	179

CAP: Control (Common agricultural practice of NPK) **E-SM**: extra-supply minerals application, $\mathbf{A_1}$: Vitamin C+Se $\mathbf{A_2}$: Vitamin E + Se and $\mathbf{A_3}$: Commercial anti-stress

agricultural practice treatments (CAP x anti-stress), indicating the efficient role of the studied new nutrients program to protect potato plants against cold stress. Upon treatment of plants fertilized with the new program with A_3 (Anti-stress commercial compound)treatment, a highest value in all vegetative growth traits was observed (Table 5) in both seasons, except for leaves area/ plant at 2nd one in which A_1 (vitamin C+Se) was the highest, resulting in an increment percentage (as average of both seasons) by 20.8, 19.4, 14.8, 14.2, 10.4, 9.4, 6.4, 4.8% in descending order for stems dry weight, number of stems/plant, stem length, leaves fresh weight, number of leaves/plant, leaves dry weight, leaves

Table 9. Tuber quality as affected by the interaction between new Nutrients program and anti-stress foliar spray at harvesting time on potato plants grown in winter plantation during 2016/2017 and 2017/2018 seasons

Treatments		**DM (%)**	**N (%)**	**P (%)**	**K (%)**	**Protein (%)**
		2016/2017				
CAP	**DW**	18.7	2.75	0.33	3.21	17.18
	A_1	18.4	2.88	0.34	3.34	17.99
	A_2	19.34	2.9	0.34	3.4	18.12
	A_3	19.26	2.81	0.34	3.43	17.56
ESM	**DW**	19.87	2.94	0.35	3.49	18.39
	A_1	20.42	3.15	0.36	3.51	19.66
	A_2	20.31	3.09	0.35	3.6	19.5
	A_3	20.77	3.17	0.36	3.58	19.83
LSD		**0.65**	0.1	0.01	0.05	0.62
		2017/2018				
CAP	**DW**	18.38	2.69	0.3	3.3	16.83
	A_1	19.4	2.8	0.33	3.34	17.5
	A_2	19.79	2.83	0.34	3.41	17.66
	A_3	19.58	2.72	0.34	3.47	17
ESM	**DW**	19.73	3	0.35	3.58	18.75
	A_1	20.75	3.19	0.36	3.61	19.93
	A_2	20.84	3.18	0.36	3.63	19.87
	A_3	20.98	3.2	0.36	3.7	20
LSD		**1.14**	**0.07**	**0.01**	**0.04**	**0.46**

CAP: Control (Common agricultural practice of NPK) **E-SM**: extra-supply minerals application, **A_1**: Vitamin C + Se **A_2**:Vitamin E + Se and **A_3**: Commercial anti-stress

area/ plant and stems fresh weight over the corresponding control (E-SM with distilled water), respectively followed by A_1 for number of stems/plant, stem length, leaves dry weight and stems fresh weight by 14.6, 9.2, 7.2 and 2.2%, respectively and A_2 for stems dry weight, leaves dry weight, leaves fresh weight and number of leaves/plant by 16, 7.2, 6.2, and 5.4%, respectively.

As for leaves area/ plant , A_2 exhibited the highest effect followed by both A_1 and A_3 without any significant among them. Concerning the quality of potato tubers in terms of elemental analysis and protein, results in Table 9 revealed that all anti-stress treatments combined with the New Nutrient Program (E-SM) gave statistically equivalent or increase values in all N, P, K and protein contents in the tubers compared to the corresponding common agricultural practice treatments (CAP x anti-stress), indicating the efficient role of the studied new nutrients program to protect potato plants against frost.

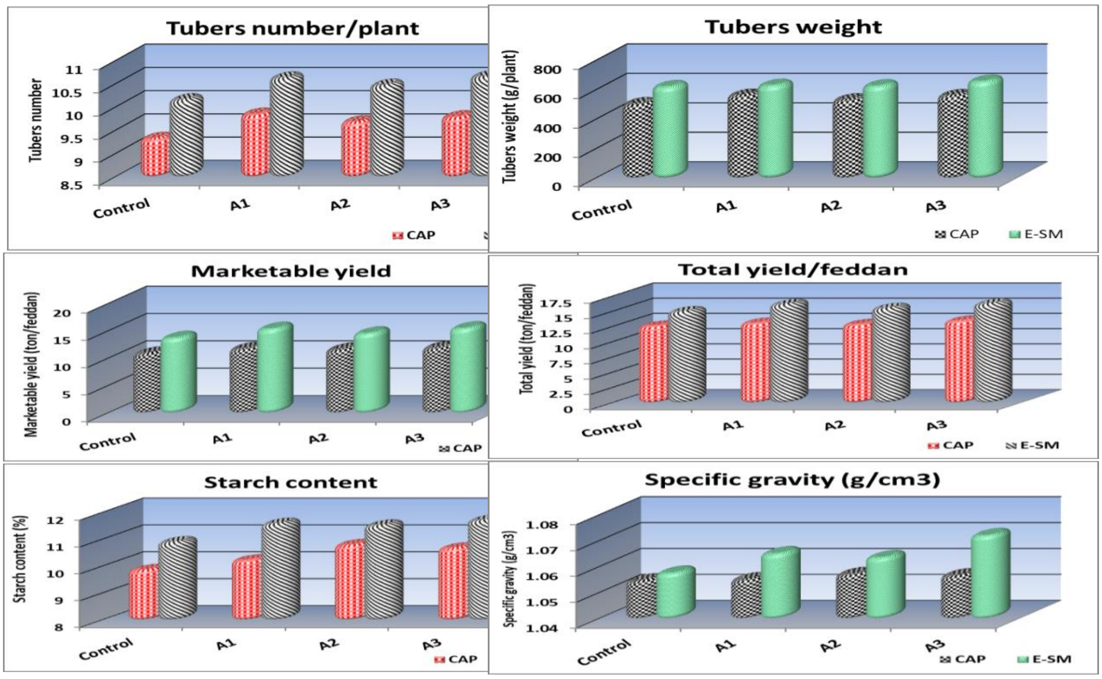

Figure 2: yield and its components (average two seasons) as affected by the interaction treatments between nutrients and anti-stressors foliar applications under cold stress

A comparison of the content of N, P, K and protein in the tubers from the plots fed common agricultural practice, the use of extra-supply application (new nutrients program) increased that component, especially after spraying with anti-stressors treatments. A_3 exhibited the significantly highest positive effects in all these traits at both seasons, resulting in an increment percentage by 7.8, 7.8, 3.7 and 2.6% for protein, nitrogen, phosphorus and potassium contents in descending order followed by A_1 for protein, nitrogen and phosphorus by 6.9, 6.9, 1.7% and A_2 for potassium content by 3.2% in 1st season and the results showed the same trend in the second season. These results are in agreement with Tripathi *et al*. (2015) who found that foliar spraying with a solution of microelements (B, Cu, Mn, Zn and Mo) on potato leaves leads to increase the absorption of N, P and the tubers' content of these mineral elements as the microelements stimulated the uptake. Meanwhile, Wichrowska and Szczepanek (2020) demonstrated that the protein content in potato tubers increased significantly due to nitrogen fertilization and affected by and weather conditions during potato growth.

Regarding to yield and its components (Figure 2), spraying the plants fed extra-supplied minerals application (E-SM treatment) with any foliar anti-stressors treatments (control-A_1-A_2-A_3) exhibited significant increasing over general control (plants that non extra-supplied minerals application, CAP) for all the traits of yield and its components except E-SM×DW for specific gravity in 1^{st} season. However, the interacted E-SM×A_3 treatment showed a maximum increment for marketable yield/fed., tuber weight, tubers yield/fed., starch content, tubers number/plant (Fig. 2), dry matter (%) in Table 9, and specific gravity (Figure 2) by 42.49, 30.14 28.69, 18.72%, 12.75 and 1.66% in descending order followed by E-SM×A_1 in all abovementioned traits by 41.64, 24.6, 28.1, 17.44, 13.94, 11.2 and 1%, respectively (as average of both seasons) over the general control. The significant increments in the obtained characters over control may be due to the protective and recovered specific transporter enzymes and/or the whole machinery under stress conditions (Palta, 1990) where, foliar application plants, with amino acids, Zn individually or in combination have beneficial effects on the metabolic potential for synthesis of amino acids, proteins, sugars and carbohydrates, as well as, their antioxidant defensive function, corresponding with normal growth and high yielding capacity (Fathy and Khedr, 2005).

Nevertheless, the beneficial effects of the applied treatments (extra-supply of minerals application, vitamin E+Se, vitamin C+Se, anti-stress compound) may be explained due to the nutritional status of plants greatly affects their ability to adapt to adverse environmental conditions, and the increase in plant growth by relatively high levels of nitrogen may be attributed to the valuable effects of N on stimulating the meristmatic activity, for producing more tissues and organs, and cell enlargement, since N plays major roles in the synthesis of structural proteins and other several macro-molecules, in addition to its vital contribution in several biochemical processes in the plant related to growth (Marschner, 1995) and may be, due to also, the functional role of calcium where, tightly related with membrane stability and integrity, signal transduction system (as a second messenger in the signal conduction between environmental factors and plant responses in terms of growth and development (Pottosin and Schonknecht, 2007), cell division and formation and involved in nitrogen metabolism. Besides, each of Ca, K and Mg are essential macronutrients for plant growth and are needed for a myriad of processes in plant metabolism (Marschner, 2011) as they roles for photosynthesis and the partitioning of photo-assimilates from source to sink organs as potato tubers are strong sink organs (Marschner, 1995) being highly dependent on the production of photo-assimilates and its translocation down to the tubers and also, the role of micronutrients in enhancing Photosynthesis and biosynthesis of proteins to protect cells and the transformation of photosynthesis products in the form of carbohydrates they are stored in the tubers (Mohamadi, 2000). Ca enables the plant to communicate information about the environment at the plant cell level (Whalley and Knight 2013) but various abiotic and biotic stimuli of the surrounding external environment such as drought or oxidative stress as well as pathogens can trigger this forwarding of information (McAinsh and Pittman, 2009).

Therefore, the roles of Ca in cell wall and plant membrane stabilization, and as a second transmitter, contribute to reducing stress severity (Ngadze *et al*., 2014). The predominant role of K in source to sink transport of assimilates is likewise based on its function as an osmotic gradient (Koch *et al*., 2019). Thus, an impact of the Ca, K and Mg supply on potato tuber development and likely quality can be expected. Generally, the plant nutrients have different functions in plant metabolism, accordingly, their influences on specific yield parameters is a complex, especially under conditions of abiotic and biotic stress (Koch *et al*., 2019 and 2020). Specific and non-specific nutrient interactions in the soil and the plants must also be taken into account.

Finally, the development of site-specific fertilization recommendations as part of an agricultural strategy is highly dependent on soil and plant nutrient status.

Brief comparison for results:

Field experiments were carried out to study the effect of foliar spray with 3 anti-stressors compound on growth and productivity of potato plants cultivated in clay loamy soil under abiotic stress, *i.e*., cold stress. Accordingly, comparing the performance of the anti-stressors on the basis of tubers yield (ton/fed.) under cold stress (Common NPK fertilization CAP in Egypt as general control) and highest desirable response for yield (% over corresponding control) under various treatments (combined cold stress with each of CAP or E-SM) as well as the effects of the anti-stress on other traits was done. The best anti-stress, which classified on the basis of these parameters, are shown in Table (10). Two out of the three studied anti-stressors were classified as a good affect source in desirable trend on yield. One out of these 2 anti-stress namely A_3 (anti-stress commercial compound) exhibited significant positive effects for tubers number/plant, tuber weight/plant, marketable yield/fed., tubers dry matter, starch content and specific gravity as well as the superiority for positive effect of most growth traits, N,P, K and protein of tubers content, indicating the possibility of combine both high yield and good quality characters under various environmental conditions. This compound, which exhibited significant positive effect for yield/fed, was also combined significant/highly significant desirable negative or positive (due to the point of view) effects for three or more important studied characters particularly vegetative growth, quality of

Table 10. The best anti-stress chosen on the basis of mean yield along with desirable significant effect for other traits comparing with general control under different conditions.

Treatment			Cold stress*	Control	Vitamin C + Se	Vitamin E + Se	Commercial Anti-stress
Increment of tubers yield (over corresponding control) and other traits under cold stress (average two seasons):							
Tubers yield	**CAP**	Ton/fed.	12.62	12.62	13.11	12.87	13.45
		%	100	100	103.81	101.98	106.51
	E-SM	Ton/fed.	12.62	14.98	16.17	15.53	16.25
		%	100	118.66	128.07	122.9	128.6
Range of other traits responses (%)			-	100.3-126.4	101.0-141.6	100.85-133.8	101.7-142.5
Desirable significant effect for other traits due to compare with the control of CAP treatment under cold stress:							
Increased traits	**E-SM**	1st season	-	a,b,c,d,e	a,b,c,d,e	a,b,c,d,e	a,b,c,d,e,f
		2nd season	-	a,b,c,d	a,b,c,d,e,f	a,b,c,d,e,f	a,b,c,d,e,f
	CAP	1st season	-	-	b,c	c,d,e	b,c,d
		2nd season	-	-	a,b,c	a,b,c,d,e	a,b,c,d
Equal traits	**E-SM**	1st season	-	f	f	f	-
		2nd season	-	e,f	-	-	-
	CAP	1st season	-	-	a,d,e,f	a,b,f	a,d,e,f
		2nd season	-	-	d,e,f	f	e,f

a: Tubers number/plant b: Tuber weight/plant c: Marketable yield/fed. d: Tubers dry matter e: Starch f: Specific gravity * General control

potato tubers in terms of elemental analysis and protein content, as well as, tubers traits….etc.

Moreover, both vitamin C+Se (A_1) showed high positive responses, in case of common fertilization (CAP) in tubers weight (g/plant) and marketable yield at the two studied seasons and vitamin E+Se (A_2) in marketable yield, tuber dry matter and starch content. However, treatment with high yield effects did not necessarily produce high other traits, especially qualitative traits and vice versa. Our results reveal that the abovementioned anti-stressors treatments might be of prime importance for traditional agricultural procedures for high yield and/or some of its important components.

Reading of the prevailing temperatures:

The knowledge of the effects of a few short periods of high or low temperature on tubers yield will be useful in the breeding of resistant varieties and in selecting better areas in which to grow potatoes. In the present work, the tolerance of cultivar Picasso to the frost stress during the growing seasons has not been confirmed. This cultivar was characterized by the relatively high tolerance of the aboveground part of plants to low temperature, but also a tendency to a decrease in the size of tubers in the total yield. Therefore, the total yield is not the only indicator of potato tolerance to frost during the growing seasons, but the assessment should also take into account the occurrence of physiological defects of tubers. An overview of the weather experienced in both growing seasons is listed in Fig.1. Day-Time temperature (2nd season compared to 1st one) increased in the month of sowing (November and slightly in December and January, that is, by 2.4, 0.5 and 0.1 °C, respectively (Fig. 1), with an increase in the night temperature in November by 1.9 °C. In opposite, Day-time temperature increased in 1st season compare with 2nd one in March by 1.9 °C. This led to an increase in the difference between night and daytime temperatures in both seasons, as follows:

The difference between Night and Day-Time temperature increased in the second season compared to the first one in November and December by 0.5 and 0.5 °C, whereas showed highly differences increasing in the three other months in 1st season by 0.1, 0.2 and 2.0 °C in January, February and March, respectively. A wide amplitude between maximum and minimum daily temperatures, results in a low or medium yield (Bueckert *et al*., 2015), however, this led to an increase in yield/fed at the second season (compared to the first one) and the opposite is true, for the number of both tubers and weight per plant. Additionally, we may have found evidence that the decrease in the total yield/fed. resulted from the fact that some plants affected by the risk of cold have died, and because of the tuber number (initiated in canopy buildup phase, P_1) is not a predictor of total yield (Minda, 2019).

Tuber yield is largely determined by growing conditions in the maximum cover phase (P_2), and the canopy decline phase (P_3). The differences between the maximum and minimum temperatures have no effect on both traits. It is clear that the average maximum and minimum temperatures (Day and Night-Time) are lower throughout November, December and February of the first season (2016/2017) than 2nd one, which led to an decrease in yield in the 1st season, compared to 2nd one (Depending on timing, intensity and duration, temperature can reduce crop growth and disrupt reproduction in 1st season, (Sadras *et al*., 2015). Also, in the second season (2017/2018), the average minimum temperatures are higher in November, January, February (tubers development phase) and March (harvesting time). However, the second season had the least difference between night and day temperature than the first one during February and March (development of tubers). In the meantime, this difference of 1st season (compared to 2nd season) was lower in the first two months.

Therefore, as shown in Figure 2, tubers number/plant (9.54&10.2), tubers weight/plant (518.1& 623.6g) and starch content in tuber (9.9&11.1%) of the plants that were grown in the first season were higher than the second season (9.11&10.1), (500.2&619g) and (9.7&10.7%) under common agricultural practices and extra-supply of mineral application (without anti-stressors), respectively. From abovementioned discussion, there was harsh cold in both seasons, and relatively frost at night-Time temperatures were recorded between January and February, *i.e*., only 3rd week of January at 1st season and each of the 2nd, 3rd and4th weeks in January and the 3rd week of February at the 2nd one (Figure 1), which led to an increase in the crop of the second season (elevated night temperature reduces tubers set and yield as (Ehlers and Hall, 1998).On the other hand, winter injury by freezing temperatures damaged the leaves of some plants, causing a reduction in leaves area/ plant and delayed growth as leaves area/ plant in 2nd season was 3085 compare with 3340 in 1st one (Table 8).The plants of potato need a moderate climate in order to grow better vegetative, but the crop needs a cold climate, not frost (Hijmans, 2003) where the frost, in Egypt, is the biggest problem at late plantings of the autumnal season and offseason growing cycles, specially the boggling agricultural seasons, which intended for export to other countries. Therefore, it was necessary to investigate the agricultural practices that provide protection from the frost conditions that the plants are exposed to during these harsh periods and are inexpensive for the farmers using exogenous application of protectants in the form of vitamins and trace elements as an anti-oxidants and nutrients this work aims to know the effect of using good and balanced nutrition of macro and micro elements and foliar spray with some anti-stressors substances on potato plants' tolerance to frost risk conditions and its effect on growth, yield and tubers quality.

Conclusively, Crop management depends on environmental parameters once the cultivar is chosen and can be improved by a wide range of measures so that yields are maximized at an acceptable risk. Many efforts have been made and still being made to overcome the problem of frost effects on potato plants which can be controlled, to a large extent, through appropriate management practices in parallel with the addition of adequate fertilizers of NPK (the rate, placement, timing and source). For example, the planting of the crop in the autumnal season (and offseason growing cycles, specially the boggling agricultural seasons), is seriously affected by the risk of night frost, in this case, the adjustment is made on the basis of field information, (before planting the crop, and during the growing season), e.g., if the beginning of the growing season has been colder than usual, as which the case of the boggling agricultural seasons, this has reflections for crop growth during the rest of the growing season, e.g. the amount of nitrogen needed to support this (and major components accompanying the addition before planting) can be adjusted using the proposed program .

In this study, good agricultural practices are suggested to reduce the effects of frosts risk as follows:

- It is recommended to fertilize the potato crop with 200 kg N/ fed., 107 kg K_2O/fed. in addition to 83 kg P_2O_5/fed., 17 kg Ca/fed., 10 kg Mg/fed. in addition, to foliar spraying with the mixture of chelated Fe, Zn and Mn (1:1:1) in 150 ppm concentrations at 40, 55 , 70 and 85 days after planting in the rate of 400 L/fed. to achieve better yields in terms of quantity and quality tubers under frost conditions.
- Half of the nitrogen fertilizer must be added to the potato crop in the form of ammonium sulfate, as it achieves higher yields of tubers and improves the quality of potatoes compared to adding the same amount in the form of ammonium nitrate only.
- Potassium fertilizer must be added in five equal doses from the first irrigation until 2-weeks before the harvest begins, while each of phosphorus, calcium and magnesium are applied once during soil preparation
- Foliar spray of selenium + vitamin (E or C) plays a vital role in reducing low temperature risk and thus increasing yield and improving potato quality.

The recommended program for planting in the off-season growing cycles will give the highest yield due to the balanced fertilization and anti-stress /anti-oxidants as well as in the same time will take care of the tubers quality. So that, the tubers yield will gain the highest values of economic competition in locally and international markets and to contribute as a good source of hard currency for Egypt.

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تحفيز قدرة نبات البطاطس على تحمل الحراره المنخفضة في الزراعات الشتوية

أحمد محمود أحمد العنانى
قسم بحوث البطاطس والتكاثر الخضرى، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر

أجري هذا البحث فى العروة الشتوية خلال موسمى 2017/2016 و 2018/2017على نبات البطاطس(صنف بيكاسو) فى مزرعة بحوث الخضربقها، محافظة القليوبية والتابعة لمعهد بحوث البساتين، مركز البحوث الزراعية وذلك لدراسة تحفيزقدرة نبات البطاطس على مقاومة مخاطر الحراره المنخفضة باستخدام المغذيات الكبرى والصغرى والرش الرزازي ببعض المواد المضادة للإجهاد

تشير النتائج أن معاملة النباتات بالتوصيات السمادية العالية من العناصر الكبرى والرش الورقي بالعناصر الصغرى مع المعاملة بمضاد الإجهاد أو أى من فيتامين ج أو فيتامين E مضافا مع السيلينيوم أدى ذلك لتحفيز مقدرة النبات على تحمل نوبات البرودة المنخفضة و تحسين نمو النبات بشكل عام وظهر ذلك واضحا من خلال عدم وجود مظاهر للإصابة بالبرودة على الشكل الظاهري للنبات . كما أظهر المركب التجاري المضاد للإجهاد بتركيز 100 جزء في المليون مع برنامج التسميد المقترح تفوقًا كبيرًا في معظم صفات النمو الخضري (طول الساق، متوسط عدد السيقان والاوراق/نبات وكذلك الوزن الطازج والجاف للسيقان والأوراق /نبات مما إنعكس ذلك بشكل إيجابي على المحصول الكلى للدرنات وصفات الجودة وخاصة المادة الجافة ونسبة النشا والبروتين فى الدرنات وذلك مقارنة بباقي المعاملات خلال موسمى الدراسة، كما تشير النتائج الى أن إستخدام عنصر السيلينيوم (50 جزء فى المليون) مع فيتامين E (250 جزء فى المليون) او فيتامين ج (150 جزء فى المليون). سجل أيضا برنامج التسميد المقترح فروق معنوية فى معظم صفات النمو الخضري والمحصول ومكوناته وذلك مقارنة بالنباتات الغير معاملة بمضادات الأكسدة ولكن تم تسميدها بالبرنامج المقترح أو مقارنة مع النباتات المعاملة وتم تسميدها بالنظام الشائع والتي سجلت قيم أقل في كل صفات النمو الخضري وكذلك المحصول.

التوصية: توصى هذه الدراسة بانه يمكن معاملة النباتات ببرنامج المغذيات الكبرى والصغرى المقترح مع الخلط بالرش الرزازي بمضاد الإجهاد او بعنصر السلينيوم مع فيتامين ج أو فيتامين E وذلك للحصول على نباتات ذات نمو خضري جيد تتحمل درجات الحراره المنخفضه مع زيادة الإنتاجية وتحسين صفات الجودة للدرنات أثناء مواسم الزراعة فى غير مواعيدها وخاصة العروة الشتويه والتي هي عروة التصدير فى مصر التى تساهم فى زيادة النقد الأجنبي.