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Comparison between Different Sources of Potassium and Proline in Mitigating the Effects of Salinity on Two Varieties of Cantaloupe

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Abstract: This work was designed to investigate the ameliorating effects of two different sources of potassium and proline on two varieties of cantaloupe Gal 152 and Boushra 411 plants grown under saline irrigation conditions. Seedlings of Gal 152 and Boushra 411 cantaloupe varieties were transplanted in North Egypt and irrigated with 5.7 dS/m saline water. Plants were sprayed with either mono potassium phosphate, Caboron or proline at concentrations of 3.0 g/l; 1.0 cm^3 /l and 1.0 g/l, respectively. Spraying took place after 3, 6 and 9 weeks after transplanting. Recorded data showed that all sprayed plants have significant higher plant height, number of branches, leaf area, total chlorophyll content, fruit yield and fruit quality compared to control plants. Mineral contents recorded also higher values for K, Mg and Ca and lower values for Na compared to untreated plants. Mono potassium phosphate recorded the highest significant effects followed by Ca boron than proline. Gal 152 showed higher responses compared to Boushra 411. Data are further discuss in relation to physiological indicators.
Keywords: Cantaloupe, Salinity, Monopotassium phosphate, Caboron, proline, yield.

Introduction:

As the population increases in Egypt passing the edge of ninety million capita, necessity to increase food production becomes a must. This increment in food production can be brought about by either expanding the cultivated land through land reclamation and/or increasing the production per unit area. However, new reclaimed lands in Egypt are usually characterized with poor fertility and/or high salinity. The latter has been aggregated more due to overuse of underground irrigation water and fertilizers. The result is a reduction in plant growth and production as well as product quality. To overcome this problem many trails and approaches have been attempted to mitigate the well-known negative effects of salinity on plant growth and production[1,2,3,4,5]. An improvement of tomato crop growth and production under saline conditions was observed as a result of application of nano calcium[6] and nano silicon[7,8]. Among those approaches is the improvement of plant nutritional status via external supplements to ameliorate salinity damages with exogenous application of N in *Phaseolus vulgaris* [9], Ca in snap bean[10] and K^+ in wheat[11]. Potassium is well recognized as the essential plant nutrient with the strongest influence on many quality parameters of fruits and vegetables[12]. It involves in numerous physiological processes that control plant growth, yield and quality parameters such as taste, texture and nutritional/health properties[13,14]. Although K is not a constituent of any functional molecules or plant structures, it is involved in numerous biochemical and physiological processes vital to plant growth, yield, and quality[13]. Adequate K nutrition has been associated with increased yields, fruit size, increased soluble solids and ascorbic acid concentrations, improved fruit color, increased shelf life, and shipping quality of many horticultural crops[14,15,16].

There are many cellular mechanisms by which organisms ameliorate the effects of environmental stresses; for instance, accumulation of compatible osmolytes such as proline is one such phenomenon. The accumulation of free proline has been studied in a number of taxa subjected to hyperosmotic stress conditions for over 45 years. The accumulation of proline under abiotic stress conditions accounts for few millimolar concentrations, depending on the species and the extent of stress[17,18]. Very high accumulation of cellular proline (up to 80% of the amino acid pool under stress and 5% under normal conditions) due to increased synthesis and decreased degradation under a variety of stress conditions such as salt and drought has been documented in many plant species[17,18,19,20,21,22,23]. In Arabidopsis, proline can account for up to 20% of the free amino acid pool after sodium chloride stress. Although proline is known to confer osmotic tolerance during stress conditions, its specific role during plant growth is not completely clear.

Proline seems to have diverse roles under osmotic stress conditions, such as stabilization of proteins, membranes and subcellular structures[24], and protecting cellular functions by scavenging reactive oxygen species[25].

Cantaloupe is considered a very profitable vegetable crop with a promising yield in the new reclaimed lands. However, as many of fruit vegetable crops, the quality of the fruits is the prime factor determining the marketable yield hence profitability to the grower.

Therefore, this works aims to investigate the effect of different sources of potassium associated with macro and or micro nutrients on the growth, yield and quality of two different cantaloupe verities crop.

Materials and methods:

Seeds of two varieties of cantaloupe plants *(Cucumis melo* L.) cv. Gal 152 and Boushra 411 were sown on 15th of January 2013 and 2014 and seedlings were transplanted on the 15th of March in the two seasons of 2013 and 2014 in a sandy soil in a private farm in the area of Wadi El-Natron, Bahaira governorate, Egypt. The soil physical and chemical analysis are shown in Tables 1 and 2. Individual transplants were grown at the bottom of ridges 100 cm width at 50 cm apart. Plot area was 1X12= 12 m^2. The drip irrigation system of GR 16 was used and plants were irrigated daily using saline-well water with an EC value 5.47 dS/m and pH of 7.8. The complete chemical analysis of the irrigation water is shown in Table (3).

All standard agricultural practices other than experimental treatments were applied according to the recommendations of the ministry of agriculture, Egypt.

Experimental treatments:

After three weeks from transplanting, plants were supplied through the irrigation system with three types of additional fertilization namely Mono potassium phosphate (KH_2PO_4) (N-P-K ratio is 0 – 52 – 34) (P_2O_5 : 52 % - K_2O : 34%); Ca boron (Boron 1.5% + chaleted Calcium 6% + Potassium 12%) or proline. The three forms were supplied to the plants at concentrations of 3.0 g /l; 1.0 cm^3/l and 1.0 g/l for M.K.P, Caboron and proline respectively.

Applications of the treatments were at 3, 6 and 9 weeks after transplanting.

Experimental design and statistical analysis:

The treatments were arranged in a split plot design with three replicates where varieties were in the main plot and fertilizer treatments in the sub main plots. Analysis of variance was carried out at probability level of 0.05 and Least Significant Difference LSD was calculated to differentiate between the treatments.

Measurements:

Plant height, number of branches, fresh and dry weights of leaves at 70 days after transplanting were measured.

Physiological measurements such as osmotic pressure in leaves tissue was estimated with relationship between total soluble solids and osmotic pressure according to[26]. Whereas, transpiration rate ($cm^{-2}s^{-1}$) and stomatal conductance (cm^{-1}**)** were evaluated using parameter machine model L1-COR, USA.

Total yield (ton/fed.) was measured by the end of the season when all ripe fruits were harvested. Average weight of individual fruits (g) was calculated as an average of individual fruits of the third picking. The same fruits were used to measure fruit diameter and total soluble solids (TSS).

Total chlorophyll content at 70 days after transplanting was measured in fully expanded leaves using Minolta SPAD 501 chlorophyll meter[27]. Also, After 70 days from transplanting total contents of K, Na, Ca and Mg (%) were chemically analyzed and measured in leaves by flame-photometer set as described by[28].

Table (1): Soil physical analysis and soil properties of the experimental farm.

Soil depth (cm3)	Total sand (%)	Silt (%)	Clay (%)	Texture
0-15	58.0	11.5	30.5	Sandy
30 – 60	57.0	13.0	30.0	Sandy

Table (2): Soil chemical analysis of the experimental farm.

Soil depth (cm3)	EC (dS/m)	pH	Soluble anions (ppm)			Soluble cations (ppm)			
			CO_3^{--}	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
0-30	4.77	7.7	55.85	31.20	10.50	24	11	10.52	2.18
30-60	4.16	7.4	51.21	22.50	16.10	16.83	6	17.80	0.097

Table (3): Chemical analysis of irrigation water (underground well) of the experimental farm.

Water sample	EC (dS/m)	pH	Soluble anions (ppm)			Soluble cations (ppm)			
			HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
Average	5.47	7.8	2.50	81.08	16.24	25.29	19.43	54.83	0.45

Results:

Data in Table (4) show the different responses and interactions of vegetative growth of two cultivated varieties and applied fertilizers treatments. It was clear that variety Gal 152 showed significant higher growth response in terms of plant height compared to Boushra 411. On the other hand all fertilizer treatments showed significant positive responses compared to control treatment. The treatment of M.K.P. recorded the highest significant effect followed by Caboron then proline. Meanwhile no significant differences were observed between the two varieties regarding number of branches nor there were significant differences in the interaction. The only significant differences were recorded in response to fertilization treatments where all treatments were positively higher than control with superiority of M.P.K. followed by Caboron then proline.

Varity Gal 152 recorded significant higher leaf area compared to Boushra 411 (Table 4). Regarding fertilization treatments, the same observed trend was recorded where all fertilizers treatments showed significantly higher positive differences compared to control treatment. Among the fertilizers treatments, M.P.K showed the highest significant difference followed by Caboron then proline.

The data of plant height and leaf area reflected on plant fresh and dry weights where Gal 152 recorded significant higher fresh and dry weights compared to Boushra 411 (Table 4). The same trend of fertilizer treatments observed above was also recorded in plant fresh and dry weights where all fertilizer treatments were significantly higher than control with the superior effect observed in M.P.K treatment followed by Caboron then proline.

Stomatal conductance as shown in Table (5) showed higher value in Boushra 411 compared to Gal 152. Meanwhile a reduction in stomatal conductance was observed with the treatment of M.K.P being the lowest followed by Caboron then proline compared to control. As a result, transpiration rate showed also a similar trend. Leaf osmotic pressure was significantly lower (negative) in Gal 152 compared to Boushra 411 (Table 5). Fertilization treatments lowered leaf osmotic pressure where M.K.P recorded the lowest leaf osmotic pressure followed by Caboron then proline.

Table (6) shows the chemical composition of the cultivated plants under the fertilization treatments. It was clear that chlorophyll content was significantly higher in Gal 152 compared to Boushra 411.

Table (4): Effect of cultivars, two sources of potassium and proline and the interaction between them on the growth characters of cantaloupe plants during seasons of 2013 and 2014.

Cultivar	Treatment	Plant height (Cm)	Branches No.	Fresh weight / plant (g)	Dry weight / plant (g)	Leaf Area Cm^2	Plant height (Cm)	Branches No.	Fresh weight / plant (g)	Dry weight / plant (g)	Leaf Area Cm^2
		2013 Season					2014 Season				
Gal 152	Control	292.67	3.30	2630.33	526.00	8551.33	278.67	3.10	2686.67	537.33	8336.33
	M.K.P (3 g / l)	424.00	4.20	2979.33	595.67	9952.33	391.67	4.33	3256.67	643.00	9960.67
	Caboron (1 cm / l)	379.00	3.93	2828.67	565.67	9732.33	365.00	4.06	2986.67	597.33	9735.00
	Proline (1 g / l)	344.67	3.70	2766.00	553.33	9711.00	320.00	3.80	2816.67	563.33	9645.00
Mean		360.08	3.78	2801.08	560.17	9486.75	338.83	3.83	2936.67	585.25	9419.25
Boushra 411	Control	279.00	3.27	2563.33	512.67	8421.00	271.00	3.30	2660.00	532.00	8417.33
	M.K.P (3 g / l)	372.33	4.37	2880.00	576.00	9876.33	381.67	4.433	2973.33	594.67	9926.00
	Caboron (1 cm / l)	317.67	3.87	2788.33	557.67	9737.67	316.00	3.97	2881.67	576.33	9739.00
	Proline (1 g / l)	303.33	3.77	2753.33	550.67	9718.33	300.00	3.87	2766.67	553.33	9645.00
Mean		318.08	3.82	2746.25	549.25	9438.33	338.83	3.89	2820.42	564.08	9431.83
Means of Treatments	Control	285.83	3.28	2596.83	519.33	8486.17	274.83	3.20	2673.33	534.67	8376.83
	M.K.P (3 g / l)	398.17	4.28	2929.67	585.83	9914.33	386.67	4.38	3115.00	618.83	9943.33
	Caboron (1 cm / l)	348.33	3.90	2808.50	561.67	9735.00	340.50	4.02	2934.17	586.83	9737.00
	Proline (1 g / l)	324.00	3.73	2759.67	552.00	9714.67	310.00	3.83	2791.67	558.33	9645.00
L.S.D at 5%	Cultivars	8.29	N.S	26.19	5.10	0.49	2.32	N.S	5.58	6.87	2.58
	Treatments	3.99	0.11	10.51	2.10	1.31	5.69	0.087	5.11	5.35	4.72
	Interaction	5.65	N.S	14.88	2.97	1.85	8.05	N.S	7.22	7.56	6.67

Table (5): Effect of cultivars, two sources of potassium and proline and the interaction between them on stomatal conductance,transpiration rate and leaf osmotic pressure of cantaloupe plants during seasons of 2013 and 2014.

Cultivar	Treatment	Stomatal conductance (cm^{-1})	Transpiration Rate ($cm^{-2}s^{-1}$)	Leaf Osmotic Pressure A.P	stomatal conductance (cm^{-1})	Transpiration Rate ($cm^{-2}s^{-1}$)	Leaf Osmotic Pressure A.P
		2013 Season			2014 Season		
Gal 152	Control	25.10	27.4	7.57	25.77	26.23	8.10
	M.K.P (3 g / l)	21.30	21.17	10.17	20.47	20.70	10.87
	Caboron (1 cm / l)	22.03	22.43	9.47	21.17	21.63	9.40
	Proline (1 g / l)	22.57	23.13	8.80	22.27	22.27	8.53
Mean		22.75	23.53	9.00	22.42	22.71	9.23
Boushra 411	Control	26.33	29.17	6.87	27.17	28.73	7.33
	M.K.P (3 g / l)	21.83	22.30	9.20	21.37	22.13	9.87
	Caboron (1 cm / l)	22.73	23.10	8.50	21.70	22.60	8.77
	Proline (1 g / l)	23.60	23.83	7.73	24.20	23.33	7.83
Mean		23.63	24.60	8.08	23.61	24.20	8.45
Means of Treatments	Control	25.72	28.28	7.22	26.47	27.48	7.72
	M.K.P (3 g / l)	21.57	21.73	9.68	20.92	21.42	10.37
	Caboron (1 cm / l)	22.38	22.77	8.98	21.43	22.12	9.08
	Proline (1 g / l)	23.08	23.48	8.27	23.23	22.80	8.18
L.S.D at 5%	Cultivars	0.07	0.09	0.11	0.17	0.02	0.11
	Treatments	0.06	0.13	0.07	0.10	0.11	0.07
	Interaction	0.08	0.18	0.10	0.14	0.15	0.10

Table (6): Effect of cultivars, two sources of potassium and proline and the interaction between them on chemical composition of cantaloupe plants during seasons of 2013 and 2014.

Cultivar	Treatment	Total chlorophyll (SPAD)	K (mg / g)	Na (mg / g)	Ca (mg / g)	Mg (mg / g)	Total chlorophyll (SPAD)	K (mg / g)	Na (mg / g)	Ca (mg / g)	Mg (mg / g)
		2013 Season					2014 Season				
Gal 152	Control	39.20	4.77	13.03	5.67	9.20	41.40	3.87	12.13	5.13	10.13
	M.K.P (3 g / l)	55.63	6.83	8.00	10.17	16.63	56.83	6.70	8.07	11.07	18.13
	Caboron (1 cm / l)	52.17	5.57	8.87	9.60	15.13	54.20	5.67	9.20	10.23	16.07
	Proline (1 g / l)	53.17	5.20	9.40	8.87	14.27	54.80	5.20	10.10	9.87	15.27
Mean		50.04	5.59	9.83	8.575	13.81	51.81	5.36	9.88	9.08	14.90
Boushra 411	Control	41.77	4.1	13.30	5.17	10.03	42.17	3.63	13.13	5.20	10.17
	M.K.P (3 g / l)	53.43	6.47	8.20	11.10	16.13	54.27	6.33	8.57	11.07	17.17
	Caboron (1 cm / l)	51.30	5.30	9.03	10.07	15.07	53.50	5.20	9.57	10.67	15.80
	Proline (1 g / l)	52.63	4.83	9.60	9.77	14.10	53.80	4.97	10.23	9.77	14.53
Mean		49.78	5.18	10.03	9.03	13.83	50.93	5.03	10.38	9.18	14.42
Means of Treatments	Control	40.48	4.45	13.17	5.42	9.62	41.78	3.75	12.63	5.17	10.15
	M.K.P (3 g / l)	54.53	6.65	8.10	10.63	16.38	55.55	6.52	8.32	11.07	17.65
	Caboron (1 cm / l)	51.733	5.43	8.95	9.83	15.10	53.85	5.43	9.38	10.45	15.93
	Proline (1 g / l)	52.90	5.02	9.50	9.32	14.18	54.30	5.08	10.17	9.82	14.90
L.S.D at 5%	Cultivars	0.16	0.09	0.05	0.04	N.S	0.09	0.04	0.11	0.04	0.05
	Treatments	0.08	0.09	0.10	0.08	0.09	0.09	0.08	0.06	0.08	0.07
	Interaction	0.12	0.13	0.15	0.12	0.12	0.13	0.12	0.09	0.12	0.10

Table (7): Effect of cultivars, two sources of potassium and proline and the interaction between them on total yield and fruit quality of cantaloupe plants during seasons of 2013 and 2014.

Cultivar	Treatment	Fruit Diameter (cm)	T.S.S (%)	Average fruit weight (g)	Total Yield (Ton /fed.)	Fruit Diameter (cm)	T.S.S (%)	Average fruit weight (g)	Total Yield (Ton /fed.)
		2013 Season				2014 Season			
Gal 152	Control	38.67	13.97	682	12.30	39.67	13.93	731.33	13.13
	M.K.P (3 g / l)	45.33	16.50	918	18.80	47.67	16.47	947.67	19.10
	Caboron (1 cm / l)	43.33	15.97	825	16.50	44.33	16.00	881.00	18.57
	Proline (1 g / l)	41.67	15.30	811	15.50	42.00	15.30	806.00	16.10
Mean		42.25	15.43	809	15.78	43.42	15.42	841.50	16.73
Boushra 411	Control	37.67	13.90	651	11.90	38.00	13.83	703.00	12.20
	M.K.P (3 g / l)	44.00	16.13	834	16.73	45.67	16.07	890.00	17.70
	Caboron (1 cm / l)	41.67	15.63	819	15.23	43.67	15.60	857.33	16.63
	Proline (1 g / l)	40.33	15.03	758	14.4	41.00	15.10	774.00	15.60
Mean		40.92	15.18	765.5	14.57	42.08	15.15	806.08	15.53
Means of Treatments	Control	38.17	13.93	666.5	12.10	38.83	13.88	717.17	12.67
	M.K.P (3 g / l)	44.67	16.32	876	17.77	46.67	16.27	918.83	18.40
	Caboron (1 cm / l)	42.5.	15.80	822	15.87	44.00	15.80	869.17	17.60
	Proline (1 g / l)	41.00	15.17	784.5	14.95	41.50	15.20	790.00	15.85
L.S.D at 5%	Cultivars	0.64	0.06	0.42	0.02	0.24	0.11	0.64	0.11
	Treatments	0.56	0.08	2.17	0.10	0.36	0.08	2.35	0.12
	Interaction	N.S	0.12	3.06	0.14	0.51	0.11	3.33	0.17

All fertilization treatments recorded significant higher chlorophyll content compared to control treatment with superiority to M.K.P treatment followed by Caboron then proline. The same trend was observed in the leaf content of K, Ca and Mg. However, Mg content did not show significant difference between the two grown varieties. The only Na content that showed an opposite trend to the previous recorded trends where Gal 152 recorded a significant lower content compared to Boushra 411. Also all fertilization treatments recorded lower Na content compared to control treatment with the lowest content recorded in M.K.P. followed by Caboron then prolin treatments.

Total fruit yield and fruit quality in terms of average fruit diameter and total soluble solids (TSS %) are shown in Table (7). Total fruit yield of cultivar Gal 152 was significantly higher than that of Boushra 411. Total fruit yield was also improved in response to the three foliar applications compared to control treatment. In this regard, MKP application resulted in the highest yield followed by Caboron then proline. Fruit quality showed the same trend where Gal 152 showed significant higher values compared to Boushra 411. Also, fertilization treatments significantly improved fruit quality compared to control treatment.M.K.P recorded the highest significant effects on all recorded parameters followed by Caboron then proline compared to control.

Discussion:

Salinity negative effects on plants has been reported to be brought about by affecting plant water status[29]. The latter affects many growth parameters in the plant such as cell elongation which appear in the forms of shorter plants and smaller leaf areas and these are what have been recorded in this study in the control plants grown under saline condition. In addition cell size (through the mechanism of K^+ transport) is the main factor affecting stomatal conductance, hence transpiration and photosynthesis rates. This means that any treatment(s) ameliorates salinity negative effects must have been improved plant water status. The applied treatments in this study have shown these ameliorating effects by one way or another.

The two sprayed fertilizers M.K.P and Caboron have potassium in different concentrations which counteracts the effect of Na and improves plants water status[30]. The degree of amelioration differed with superiority of M.K.P probably because the associated nutrient with K in both fertilizers must have been playing a role in increasing its absorption rate by the plant and/or its affectivity once it is in the plant. Previous controlled environment studies[14,15] have shown that supplementing soil K supply with foliar K applications during fruit development and maturation can improve muskmelon fruit quality parameters such as fruit firmness, sugar content, ascorbic acid and beta-carotene levels. The effectiveness of MKP on ameliorating salinity effects has been previously reported by[31]. On the other hand, Caboron has chelated Ca which is well documented to counteract the Na negative effects[32,33] probably through transport and discrimination of salts[34] and/or improved osmotic adjustment due to accumulation of osmoregulators in the root system as a result of the interaction between Na^+ and Ca^{2+} [35]. This may be the reason for the improving effects of Caboron observed on saline irrigated plants. In addition, Caboron has 12% K content which is also an essential nutrient in improving plant water status and plant growth. In this regard,[36] reported an improvement in plant water status through reduction in transpiration and stomatal conductance by the addition of potassium or phosphorus with a lesser effect to the latter. This is probably the reason that M.K.P showed stronger effect than Caboron. Meanwhile, proline with its documented positive effects on ameliorating salinity effects have proved these effects in this study and improved plant growth and production compared to control plants. The effect of proline may be brought about by stabilization of proteins, membranes and subcellular structures[24], and protecting cellular functions by scavenging reactive oxygen species[25]. However the effect of proline as an osmoregulator was not as high as the other two sprayed compounds which indicates that other factors must have been playing roles in these effects. It might be the stimulating effects of some nutrients to the others which increase the final observed effects of those applied compounds. The overall effects of these treatments were observed in the forms of higher plant height and leaf area with better stomatal conductance which means higher photoassimilation rates compared to control plants. This was interpreted in the form of higher plants fresh and dry weights as well as higher fruit yield. Since K is playing role in assimilate transportation, the quality of fruits in terms of weight and TSS must have been increased and this is what have recorded in this study. The different degree of responses between the two varieties must be due to the genetic characteristics of each variety although it showed the same general trends.

It could be concluded that applying supplementary fertilization such as monopotassium phosphate, Caboron and proline can ameliorate the negative effects of salinity and improve fruit quality of cantaloupe plants with superior effects of monopotassium phosphate.

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