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Effect of Nitrogen Forms and Biostimulants Foliar Application on the Growth, Yield and Chemical Composition of Hot Pepper Grown under Sandy Soil Conditions

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Abstract: A study was conducted in order to assess the effect of different N fertilization forms (ammonium sulfate, urea, calcium nitrate and ammonium nitrate) and biostimulants foliar application (potassium humate or potassium citrate) on the growth, yield and nutritional content of hot pepper fruits (*Capsicum annuum* L) cv. Mansoura. Vegetative growth, fruit yield components and fruit nutritional value expressed as titratable acidity, total soluble solids, total carbohydrates, vitamin C, anthocyanin, total polyphenols, tannins and mineral content (nitrate, Ca and K) were determined. The most vigorous vegetative growth and highest fruit yield were obtained when hot pepper plants were fertilized with ammonium nitrate and sprayed with potassium humate as a biostimulation. Furthermore, ammonium nitrate combined with potassium humate foliar spray recorded the best nutritional value indicators i.e., total carbohydrates, anthocyanin, ascorbic acid, total polyphenols and tannins content. On the other hand, fertilization with urea without adding any foliar biostimulants resulted in the lowest vegetative growth, yield, fruit characteristics and nutritional value. Generally, nitrate form (with superiority to ammonium nitrate over calcium nitrate) was better than ammonium sulfate form followed by urea form in most of the measured parameters. Also potassium humate was better than potassium citrate as biostimulant material.

Key words: *Capsicum annuum*- N forms- Biostimulation- K citrate- K humate- quality- antioxidant- ascorbic acid

INTRODUCTION

Hot pepper (*Capsicum annuum* L.) is one of the most valuable vegetable crops grown in newly reclaimed land in Egypt. Peppers are an important source of nutrients in the human diet and an excellent source of vitamins A and C as well as phenolic compounds which are important antioxidants. Levels of these compounds can vary by genotypes and maturity as well as growing conditions[22]. Growth, yield and nutritional value of vegetable crops are largely affected by the applied fertilizers[40]. So, it is imperative to grow the crop under the most optimum nutrient conditions, thus the producer can get the highest profitable yield and also to obtain fruits rich in the nutritional constituents which are vital for health[32].

Nitrogen (N) is one of the major nutrients that has many important roles in plant development and physiological process. Improved N management can be achieved by matching N supply with crop needs, improved timing of fertilizer application, and selecting appropriate N sources[23].

Usually plants are able to take up N as nitrate (NO_3^-) and ammonium (NH_4^+), but some may prefer one source or another depending on plant species[29]. N sources may affect plant growth via many processes within the soil plant system and inside the plant[51].

The most predominant N forms in commercial fertilizers in Egypt are: nitrate (NO_3), ammonium (NH_4) and urea (NH_2). Several researchers studied the effect of N source on different vegetable crops but no or little investigations had studied the effect of different N forms on growth and chemical composition of hot pepper plants under Egyptian newly reclaimed land.

The response of pepper plants to N form varies where the nitrate form gave taller plants with bigger girths, which looked greener, had more fruits and gave higher yield than the other N sources. Since fertilizing N in nitrate form gave 72-101% greater yields than ammonium form[35]. Similar results were obtained by Sarro *et al.*[39] where using NH_4^+-N decreased fruit yield specially when it was applied for longer periods during the growing season. However, the highest fruit yield of bell pepper grown on plastic mulch was obtained with sulfer coated urea, when compared to pepper grown with urea, ammonium nitrate or ammonium sulfate[28].

Moreover, Houdusse *et al.*[24] mentioned that ammonium and/or urea nutrition caused a significant decrease in pepper plant growth and the presence of nitrate corrected the negative effects of mixed nitrogen forms containing ammonium and/or urea on plant growth. Moreover, the authers concluded that using mixed nitrogen forms containing urea did not cause any negative effect on mineral content since plants fed on

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mixed nitrogen forms containing urea had higher shoot concentrations of potassium, phosphorus, iron and boron than plants receiving nitrate. Also the highest plant growth, fruit yield, and largest leaf area in hydroponically grown zucchini squash (*Cucurbita pepo* L. cv. Green Magic) resulted when NO_3-N was the sole form of N than when NH_4-N was part of the N treatment[11].

On the other hand, Xu *et al.*[52] reported that N form had no significant effect on early fruit yield of sweet pepper (*Capsicum annuum* L. cv. Hazera 1195) while, replacing of NO_3-N by NH_4-N increased total fruit yield. Also, Guertal[21] found that there were few differences in pepper yield or quality due to N source.

In many production areas, foliar spray with biostimulant products are becoming more common for the purpose of improving production quantity and quality. These products vary in chemical composition and often contain mixture of organic and inorganic compounds including essential macro- and micronutrients, humates, citrates and amino acids[7,14]. Humic substances appear to be beneficial in chelating nutrients, preventing their tie up on plant leaves and improving conductivity of nutrients into plant tissue, resulting in more efficient utilization of nutrients[7]. Potassium humate can be used as organic potash fertilizers. It supplies high levels of soluble potassium in readily available forms. Combined with humic acid, potassium, can be rapidly absorbed and incorporated into plant whether via soil or foliar application methods. Enhancement of plant growth using potassium humate had been reported to be due to increasing nutrients uptake such as N, Ca, P, K, Mg, Fe, Zn and Cu[1,16] enhancing photosynthesis, chlorophyll density and plant root respiration which resulted in greater plant growth and yield[12,43,44]. In North Florida, Castro *et al.*[9] reported a 17% yield increase of large tomato fruits with application of humic acid compared to the control treatment in micro irrigated culture. On the other hand, there is several reports indicated the beneficial effect of citric acid on plant growth and one of the major roles of citric acid is to reduce phytotoxicity and thus increasing yield and quality[13].

The main interest in this study was to determine the most proper nitrogen fertilizer form for newly reclaimed sandy soil and also to find whether biostimulants (potassium humate or potassium citrate) had a beneficial effect on early and total yields well on fruit quality of hot pepper.

MATERIALS AND METHODS

Plant Material and Experimental Conditions: Two field experiments were conducted at the Experimental Station of National Research Centre at Nubaria region, North Egypt in 2007 and 2008. The experimental site had a sandy soil texture with pH of 7.6, EC of 0.19 (Ds/m in soil paste) and the organic matter was 0.21 (%) with 14.00, 8.90, 15.60 mg/100 g soil of N, P, and K respectively.

Plant Material: A 4-weeks-old hot pepper seedlings (*Capsicum annuum* L) cv. Mansoura Hybrid F1 (Fito Semillas seed Co., Barcelona, Spain through their agent Grow tech Co., Cairo Egypt) were obtained from a local commercial nursery. Healthy seedlings of uniform size were selected and transplanted on Feb. 26, 2007 and Feb. 28, 2008. At soil preparation, full dose of P_2O_5 (90 kg/fed) as single super phosphate (15% P_2O_5, Abo Zabal Co. for Fertilizers, Cairo, Egypt) and half dose of K_2O (60 kg/fed) as potassium sulfate (50% K_2O, SOP standared, Tessenderlo Group, Brussels, Belgium) plus compost (5 tons/feddan, El-Nile Compost Co., El-Minia, Egypt) were added, and the mixture were then incorporated into the top 15 cm of the ridge soil. While remaining K dose was applied 45 days after transplanting. After one week of transplantation, dead seedlings (~5%) were replaced by planting fresh seedlings to obtain a uniform stand. A drip irrigation system was designed for the experiment. Laterals were laid in each plant row (70 cm apart), and inline emitters (with discharge rate of 2 L/h) were spaced at 30 cm intervals with three transplants per drip. Regular standard agricultural practices common in the area as recommended by Egyptian Ministry of Agriculture were followed. Irrigation was carried out regularly each other day when the water level reach about 75% of the field capacity. First hoeing and weeding was carried out 20 days after transplantation and two more weedings were carried out at one month interval.

Treatments:

Nitrogen Fertilizer Application: Four different types of nitrogen sources were tested in this experiment namely ammonium sulfate (20.6% N), urea (46% N), calcium nitrate (15.5%N) and ammonium nitrate (33.5% N). The N fertilizers were added with the same rate (150 kg N per feddan) at 4 equal doses, the first application was with soil preparation and the second application was 30 days after planting and then at 14 days interval.

Biostimulants Application: After 30 days from transplanting, the plants were sprayed twice at 15 days intervals with either potassium humate (0.5 g/l) or potassium citrate (1 g/l). At the same time, control treatment was sprayed with water to exclude the effect of spraying.

Treatments details are provided below:

T1 = Ammonium sulfate + Control (water)
T2 = Ammonium sulfate + K humate
T3 = Ammonium sulfate + K citrate
T4 = Urea + Control (water)
T5 = Urea + K humate
T6 = Urea + K citrate

T7 = Calcium nitrate + Control (water)
T8 = Calcium nitrate + K humate
T9 = Calcium nitrate + K citrate
T10 = Ammonium nitrate + Control (water)
T11 = Ammonium nitrate + K humate
T12 = Ammonium nitrate + K citrate

Measurements:

Vegetative Growth and Yield Parameters: Four whole plant samples per plot were selected 75 days after transplanting for determination of the vegetative growth (plant height, number of branches as well as plant fresh and dry weights). Another 5 plants were selected for determination of early yield. When the fruits reached their maturity, plant yield of ripe fruits were harvested. The plants were harvested 3 times during the season. Yield was determined by counting and weighing all mature fruits on each plant. First harvest was considered as early yield and the combined yield of the 3 harvests was considered as total yield. Also total yield per feddan was calculated.

Fruit Physical Characteristics: Random samples of 20 fruits in each treatment were selected to measure the physical characteristics of the fruit where fruit length and diameter and also fruit fresh and dry weight were measured.

Fruit Chemical Quality Parameters:

Determination of Organoleptic Properties: Organoleptic properties are the properties related to color, odor and taste. In this work organoleptic properties were evaluated by measuring total soluble solids (TSS) and titratable acidity. About ten grams fresh fruit sample was blended and the juice was used to measure TSS using standard handheld refractometer. Titratable acidity in fruit juice was measured by volumetric titration with standardized 0.1N sodium hydroxide, using phenolphthalein as an internal indicator and expressed as % citric acid[4].

Determination of Nutritional Value:

I- Determination of Total Carbohydrates: A known mass (0.5 g) of dried fruits was placed in a test tube, and 10 ml of sulfuric acid (1N) was added. The tube was sealed and placed overnight in an oven at 100ºC. The solution was then filtered into a measuring flask (100 ml) and completed to the mark with distilled water. The total sugars were determined colorimetrically according to the method of Smith *et al.*[45]

II- Determination of Ascorbic Acid (Vitamin C): Vitamin C was determined by using the 2,6, dichlorophenol-indophenol dye (Sigma Chemical Co. St. Louis, MO, U.S.A., Product Number D1878) titration method[34] where 1 g of fresh fruit tissue was weighed and grounded using mortar and pestle with addition of 2 ml of metaphosphoric acetic acid (Al-Gomhoreya Co. for Chemical Industries, 95%). The mixture was filtered and the extract was made up to10 ml with the metaphosphoric-acetic acid mixture. Five ml of the metaphosphoric-acetic acid solution was pipetted into 25 ml flask followed by 2 ml of the samples extract. The samples were titrated separately with the indophenol dye solution until a light rose pink persisted for 5 sec. The amount of dye used in the titration was determined and used in the calculation of vitamin C content (mg/100g FW).

III- Determination of Anthocyanin: Anthocyanins were determined in air dried pepper fruits as the method described by Tibor and Francis[48]. A mixture of ethanol 95% and 1.5 N HCl (85:15) was prepared and its pH was adjusted to 1. A known mass was macerated with 50 ml extracting solvent and stored at 4°C overnight. The sample was filtered on whatman No.1 filter paper. The extract was completed to a known volume with extracting solvent. The color of the extract was measured at the absorption maximum (520nm) using Shimadzu spectrophotometer model UV 1201.

IV- Determination of Total Polyphenols: Half gram of dried fruits was blended with 40 ml of 70% aqueous acetone then boiled to extract the total polyphenols and was left to cool. The mixture was then filtered using whatman No. 1 filter paper and the residue was mixed with another 20 ml of 70% aqueous acetone and the extraction process was repeated twice. The collected extracts were combined and completed to a final volume of 100 ml. Ten drops of concentrated hydrochloric acid were added to 1ml of the extract, and then heated rapidly to boiling in a water bath for about 10 minutes. After cooling, 1ml of the Folin–Ciocalteu reagent and 1.5 ml of sodium carbonate solution (14%) were added. The mixture was diluted to 10 ml with distilled water then thoroughly mixed. The reaction mixture was heated in boiling water for 5 minutes, and then cooled. The developing color was measured at 520 nm using Shimadzu spectrophotometer model UV 1201 as described by Wettasinghe and Shahidi[50].

V- Determination of Tannins: Tannins of the dried fruits were determined using the modified vanillin hydrochloric acid (MV-HCl) as reported by Maxson and Rooney[31]. Samples of 1 gram dried fruits were extracted with 1% concentrated hydrochloric acid in methanol. The mixture then were shaken for 24 hours and let to settle. A 5 ml of vanillin-HCl reagent (50:50 mixture of 4% vanillin / 8% HCl in methanol) was quickly added to 1 ml extract. The developed color was measured at 500 nm using Shimadzu spectrophotometer model UV 1201. By plotting the optical densities against catechin concentrations, the standard curve was obtained and tannins % was calculated.

Determination of Fruit Mineral Content: Nitrate content in the fruits was measured as described by Agbaria *et al.*[2]. Moreover, Ca and K were determined by atomic absorption spectrophotometer using perkin Elmer Model 370A as described by Chapman and Pratt[10].

Experimental Design and Statistical Analysis: The experimental design used in the two successive seasons was a randomized complete block with four replicates. The obtained data were statistically analyzed using ANOVA and means separation was done using LSD test according to the method described by Gomez and Gomez[20].

RESULTS AND DISCUSSION

The dramatic increase in using fertilizers and higher production costs in the recent years requires more attention from producers to reduce pollution and production cost. This reduction can be obtained by selecting the proper form of fertilizers that is suitable for the soil type and plant species as well as using a beneficial biostimulants foliar spray to obtain a real increase in crop yield, and quality and thus has a high economic return. This research aimed to examine effect of the different N forms and some biostimulant foliar sprays available in Egypt on yield and quality of hot pepper grown under newly reclaimed sandy soil conditions.

Vegetative Growth and Yield Parameters: Data presented in Table (1) shows clearly that N fertilization form and biostimulant foliar application interacted significantly and had a positive effect on all the vegetative growth parameters. It was clear that the highest value for plant height was obtained by applying ammonium nitrate (fertilizer) combined with spraying potassium citrate (biostimulant), while the shortest plants were achieved when plants were fertilized with ammonium sulfate either without biostimulant foliar application or when plants were treated with potassium citrate. On the other hand, combining ammonium nitrate with potassium humate resulted in the highest number of branches/plant as well as plant fresh and dry weight in the two studied seasons. Whereas urea treatment without biostimulant application (control) resulted in the lowest value for all these vegetative growth parameters except plant height (statistical analysis of the experimental data showed a similar trend in both seasons; thus a combined analysis for all studied parameters in the two studied seasons was presented).

Form these results, it was noticed that the best N fertilizer form was ammonium nitrate followed by calcium nitrate, ammonium sulfate and lastly coming urea in all vegetative growth parameters except for plant height where urea resulted in taller plants than ammonium sulfate. Regarding biostimulant application, potassium humate was more effective than potassium citrate in increasing all the studied vegetative growth parameters and both of them showed a significant increase over the control. In respect to, plant height there was no statistical difference between potassium citrate and humate but both biostimulants were significantly higher than control.

Several researches found that applying nitrogen fertilizer in the form of ammonium nitrate gave the most vigorous vegetative growth of potato plants[5,41]. The enhancement of plant growth due to fertilizing with ammonium nitrate may be attributed to the presence of both N forms, nitrate (NO_3^-) and ammonium (NH_4^+) that is documented to be superior over sole NO_3^-- N or NH_4^+- N sources[29]. On the contrary, using ammonium sulfate resulted in a weak growth of potatoes plants[15].

Moreover, the enhancement of plant growth using potassium humate had been reported to be due to the increase in nutrients uptake[1,16]or enhancement of photosynthesis, chlorophyll density and plant root respiration which resulted in greater plant growth[12,43,44]. Regarding the yield parameters, it was clear from the illustrated data in Fig. (1) that there was a positive interaction between the two studied factors i.e., N forms and biostimulation foliar spray in increasing all yield components of hot pepper plants.

Ammonium nitrate combined with potassium humate foliar spray was the best treatment for increasing the total yield per plant and also per feddan. While applying urea with or without potassium humate resulted in the lowest total fruit yield. On the other hand plants received ammonium nitrate without biostimulant application had the highest early yield followed by calcium nitrate combined with potassium humate foliar spray. Moreover, data presented in Fig. (1) show that biostimulation either with potassium humate or citrate had a statistical significant effect on total yield per plant and per feddan, but it had little or no significant effect on early yield per plant. This is might be due to the vegetative growth stimulation by foliar application of potassium humate or citrate which resulted in a positive delay in flowering and fruiting stages.

Similar results were obtained by Bryan[8] and Castro *et al*.[9] who mentioned that there was an increase in tomato fruit yield with application of humic acid compared to the control treatment. Moreover, Ebeed and El-Migeed[17] reported that the presence of K-citrate in spraying solution with sucrose had a beneficial effect on increasing fruit set, retention and yield in mango when compared to sucrose treatment only.

Fruit Physical Characteristics: Fruits number per plant well fruit fresh and dry weight followed a similar trend as mentioned above (Table 2) where combining ammonium nitrate fertilizer and potassium humate foliar spray gave the highest significant values of fruits number per plant and fruits fresh and dry weight as compared with other treatments. Generally ammonium nitrate was the best N form followed by calcium nitrate then ammonium sulfate and lastly urea while potassium humate was superior to potassium citrate and both were significantly higher than control. Similar results were obtained by Soltani *et al.*[46] who mentioned that increasing NH_4-N in nutrient solution caused reduction in cucumber fruit dry matter. Moreover, Krsti *et al.*[26] reported that shoot dry weight of sugar beet was dependent on the form and concentration of N- present in the nutrient solution and the lowest value was obtained in the presence of ammonium as the sole N-source. The simulative effect of potassium humate in enhancing fruit characteristics may be attributed to that some plant hormone-like substances seem to be present in the humic substances, thus exerting a possible stimulating effect on fruit growth[36].

Regarding fruit length and fruit diameter, there was no significant effect for both N forms and biostimulants foliar spray and this might be because these parameters is related more to the genotype than environmental effect.

Fruit Chemical Quality Parameters:

Organoleptic Properties: Organoleptic properties expressed as TSS and acidity in hot pepper fruits (Fig. 2) were significantly affected by both studied factors. Hot pepper plants received ammonium nitrate combined with potassium humate foliar spray had fruits with best organoleptic indicators i.e., TSS and acidity. Results of Tabatabaei *et al.*[47]indicted that TSS of strawberry fruits was increased with increasing NH_4 ratio in the nutrient solution. Moreover, liquid fertilizer containing humic acid increased apple fruit weight, yield and soluble solid content[27].

Nutritional Value: This work results of vegetative growth and yield (Tables 1, 2 and Fig.1) were in harmony with the results of nutritional value indicators of fruits (Figs 3 and 4). Nitrogen fertilization form and biostimulation foliar spray treatments on hot pepper plants were significantly interacted and enhanced all nutritional value indicators. Hot pepper plants received N in the form of ammonium nitrate combined with potassium humate foliar spray recorded the best nutritional value indicators i.e., total carbohydrate contents, anthocyanin, ascorbic acid, total polyphenols, and tannins (Figs. 3 and 4) than the other treatments. This significant increase may be attributed to the favorable effect of this treatment on fruit weight (Table 2), thus affecting the various constituents of fruits.

However, when investigating the individual effect of each studied factor it was clear that nitrate form was better than ammonium form and lastly coming the urea form in all fruit nutritional value indicators. Whereas, potassium humate was better than potassium citrate as biostimulator material on all the nutritional value indicators. In respect to N forms, it was obvious that stimulating effect of ammonium nitrate > ammonium sulfate > calcium nitrate > urea in case of carbohydrate, total polyphenols and ascorbic acid contents. The improvement in carbohydrate content due to ammonium nitrate application with or without biostimulates was highly significant when compared to other treatments. Regarding tannin content, all N forms had approximately the same effect. In case of anthocyanin content, it was clear that Ca nitrate effect > ammonium sulfate > ammonium nitrate > urea. While, combination between K-citrate and urea decreased anthocyanin when compared to urea treatment. Nitrogen is considered a master element in plant nutrition and it plays an important role in all physiological growth processes of plant as stimulation of plant growth, yield and chemical constituents in different plants. However, considerable differences existed in the response of various species to different N fertilizer forms. In addition to, organic and/or inorganic fertilizers exert beneficial effects on nutritional value of snap bean[18] and on soybean[3]. Thus, the increase in carbohydrate content may be due to the activation of photosynthetic machinery as a result of stimulating effect of different N forms on photosynthetic process as N is a constituent of chlorophyll molecules. Moreover, the increase in phenolic content may be attributed to the increase in carbohydrate content. Since, phenolic compounds occur in pepper in connection with sugar[30]. Data illustrated in Fig (3 and 4) similar to that obtained by Naguib *et al.*[33] who mentioned that N forms markedly increased soluble sugar content (total, reducing and non reducing) and stimulated ascorbic acid formation in radish roots. Whereas, Zhang *et al.*[54] reported that sucrose, glucose and ascorbic acid content of spinach was decreased by increasing N- doses. Moreover, the highest ascorbic acid concentration of spinach was recorded with ammonium sulfate followed by ammonium nitrate and the lowest was recorded with urea[38]. Regarding to biostimulants, the humic substances can affect plant physiology and stimulate growth due to their hormone-like activity. Humic substances have cytokinin and auxin like activity 100 and 10 times lower than that of benzyladenine and indol acetic acid respectively[6]. Chen and Avaid[12] and Zaghloul *et al.*[53] stated that foliar application of potassium humate increased soluble sugar content of *Thuya orientalis* L shoots compared to control. Moreover, foliar application of humic acid significantly increased ascorbic acid and endogenous antioxidants of Kentucky bluegrass[55]. The most interesting result in this study is the increase of ascorbic acid, total polyphenols and anthocyanin in pepper fruits resulted from the application of two studied factors. Since, these compounds play an important role in increase fruit quality as they considered important antioxidants for human nutrition[22]. These antioxidants perform their function by counteracting the oxidizing effect on lipids by scavanging highly reactive oxygen free radicals.

Fruit Mineral Content: As shown from data presented in Fig (5) that N forms had a positive effect on the mineral content of hot pepper fruits. Furthermore, biostimulants foliar spray, either with potassium humate or citrate, significantly increased fruit mineral content as compared with control plants. However, there were no statistical significant difference between both of the two tested biostimulators on fruit mineral content. Nitrate form supplied either as ammonium nitrate or calcium nitrate significantly increased nitrate content over ammonium sulfate followed by urea. This result is in accordance with that of Wang *et al.*[49] who mentioned that nitrate accumulation in spinach shoots was dramatically increased with the increase of NO_3^--N in the nutrient solution. Also, concentration of nitrate in plant tissues was found to be dependent on the concentration of N- present in the nutrient solution[26]. On the other hand, Saleh *et al.*[37] noted that organic fertilizer and humic acid significantly decreased nitrogen nitrate content and improved fruit quality of treated vines.

Concerning to potassium and calcium content, it was noticed that nitrate form supplied either as ammonium nitrate or calcium nitrate significantly increased both elements as compared with other N forms. Both nitrate and ammonium can be taken up and metabolized by plants. Since, increasing the level of NO_3 in the growing media stimulates organic anion synthesis and hence, cation accumulation. However, N forms preferential for crop growth much depends on plant species and other environmental factors[19]. Results obtained in this work are in agreement with those of Kotsiras *et al.*[25] who stated that the concentration of K, Ca, Mg and NO_3 in all regions of cucumber fruit was higher when NO_3 constituted 75% or more of the total N in the nutrient medium, but was reduced by increasing concentrations of NH_4.

Also, other researches reported that total uptake of Ca, Mg, and K decreased with increasing NH_4-N proportion in the nutrient solution which suggests that NH_4-N was competing with these cations in hot pepper[39] and zucchini fruits[11]. Whereas, Salman *et al.*[38] reported that applying N as ammonium nitrate significantly increased Ca content of spinach leaves as compared with ammonium sulfate and urea. In respect to biostimulants, it was found that K- humate have an enhancing effect on the absorption and translocation of minerals ,this may be due to its effect on enhancing metabolism[42].

Table 1: Effect of different N fertilization forms and biostimulants foliar spray on vegetative growth of hot pepper plants (combined analysis of 2007 and 2008 seasons).

Treatment		Plant height (cm)	No. of main branches	Plant fresh weight (g)	Plant dry weight (g)
Urea	Control	31.50	3.50	87.54	19.90
	K humate	34.00	4.50	118.20	24.52
	K citrate	31.75	5.00	107.31	24.17
	mean	32.42	4.33	104.35	22.86
Ammonium nitrate	Control	31.50	4.15	105.70	22.82
	K humate	37.50	5.50	154.53	33.37
	K citrate	46.50	4.50	142.40	30.75
	mean	38.50	4.72	134.21	28.98
Ammonium sulfate	Control	28.75	4.00	94.48	21.40
	K humate	30.50	4.50	134.50	28.04
	K citrate	28.00	4.50	119.38	25.78
	mean	29.08	4.33	116.12	25.07

Table 1: Continue

Calcium nitrate	Control	32.50	4.25	113.55	23.20
	K humate	40.50	5.50	139.45	30.11
	K citrate	38.00	4.50	126.50	28.96
	mean	37.00	4.75	126.50	27.42
Biostimulant	Control	31.06	3.98	100.32	21.83
Average	K humate	35.63	5.00	136.67	29.01
	K citrate	36.06	4.63	123.90	27.41
LSD	N	1.76	0.29	6.41	1.34
	B	1.87	0.28	7.12	1.45
	N*B	0.90	0.62	0.62	0.23

Table 2: Effect of different N fertilization forms and biostimulants foliar spray on fruit characteristics of hot pepper plants (combined analysis of 2007 and 2008 seasons).

Treatment		Fruit no./plant	Fruit length (cm)	Fruit Diameter (cm)	Fruit FW (g)	Fruit DW (g)
Urea	Control	69.3	12.95	1.63	5.64	0.57
	K humate	82.6	12.08	1.67	6.90	0.68
	K citrate	72.1	12.55	1.50	7.94	0.78
	mean	74.67	12.53	1.60	6.83	0.68
Ammonium nitrate	Control	113.4	13.05	1.70	7.04	0.71
	K humate	121	12.73	1.75	10.68	1.01
	K citrate	117.9	12.05	1.83	7.86	0.74
	mean	117.43	12.61	1.76	8.53	0.82
Ammonium sulfate	Control	79.1	12.76	1.65	7.49	0.73
	K humate	94.7	11.63	1.60	6.63	0.64
	K citrate	93.1	12.30	1.63	9.41	0.91
	mean	88.97	12.23	1.63	7.84	0.76
Calcium nitrate	Control	101.5	13.00	1.78	6.96	0.66
	K humate	117.6	11.75	1.50	8.15	0.82
	K citrate	109.9	12.03	1.53	8.59	0.84
	mean	109.67	12.26	1.60	7.90	0.77
Biostimulant	Control	90.83	12.94	1.69	6.78	0.67
Average	K humate	103.98	12.04	1.63	8.09	0.79
	K citrate	98.25	12.23	1.62	8.45	0.82
LSD	N	5.21	NS	NS	0.98	0.03
	B	4.98	NS	NS	0.34	0.07
	N*B	5.45	NS	NS	1.05	0.09

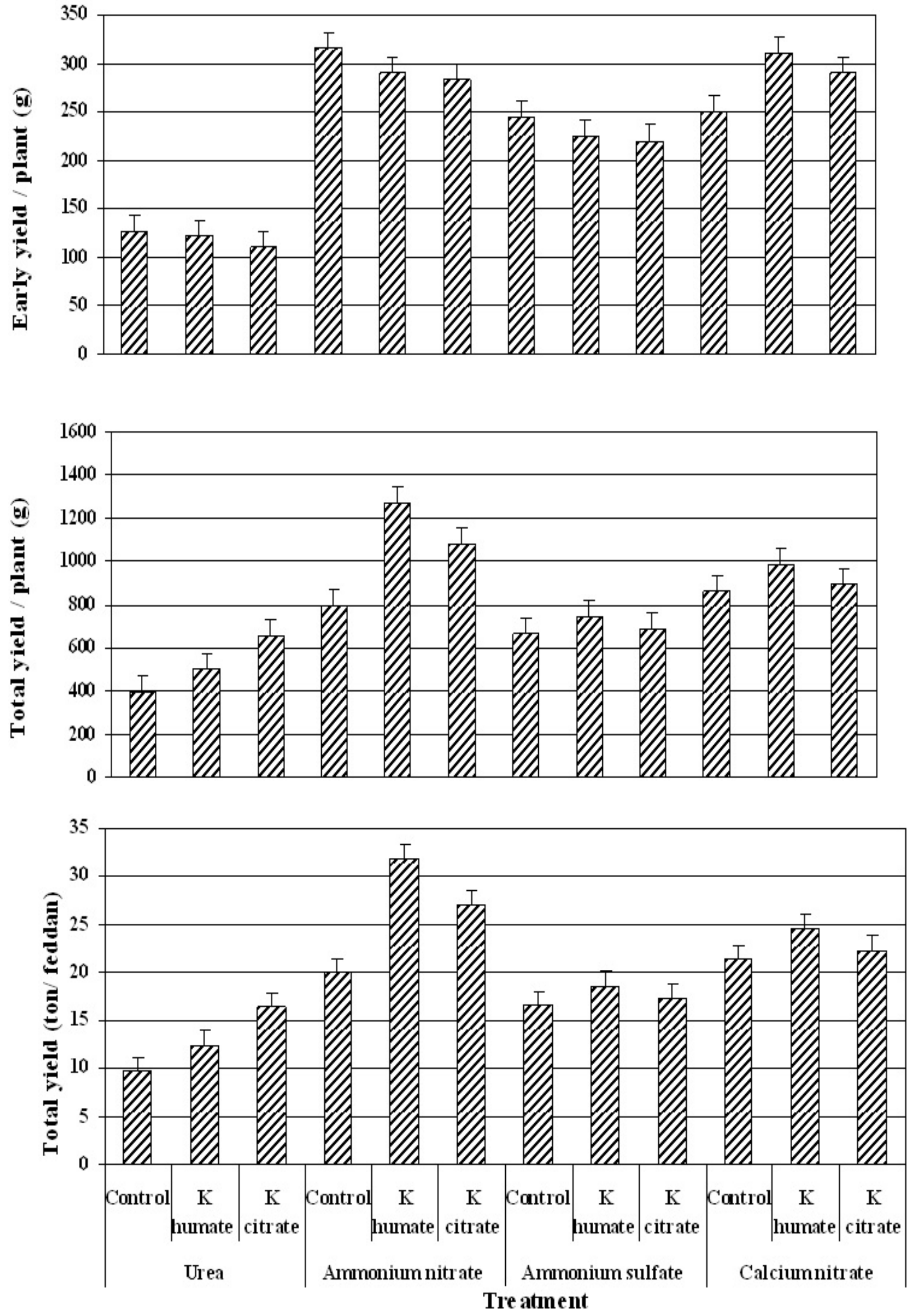

Fig. 1: Effect of nitrogen form and biostimulant foliar spray on early and total yieldof hot pepper. Vertical bars present LSD value at p ≥ 5%.

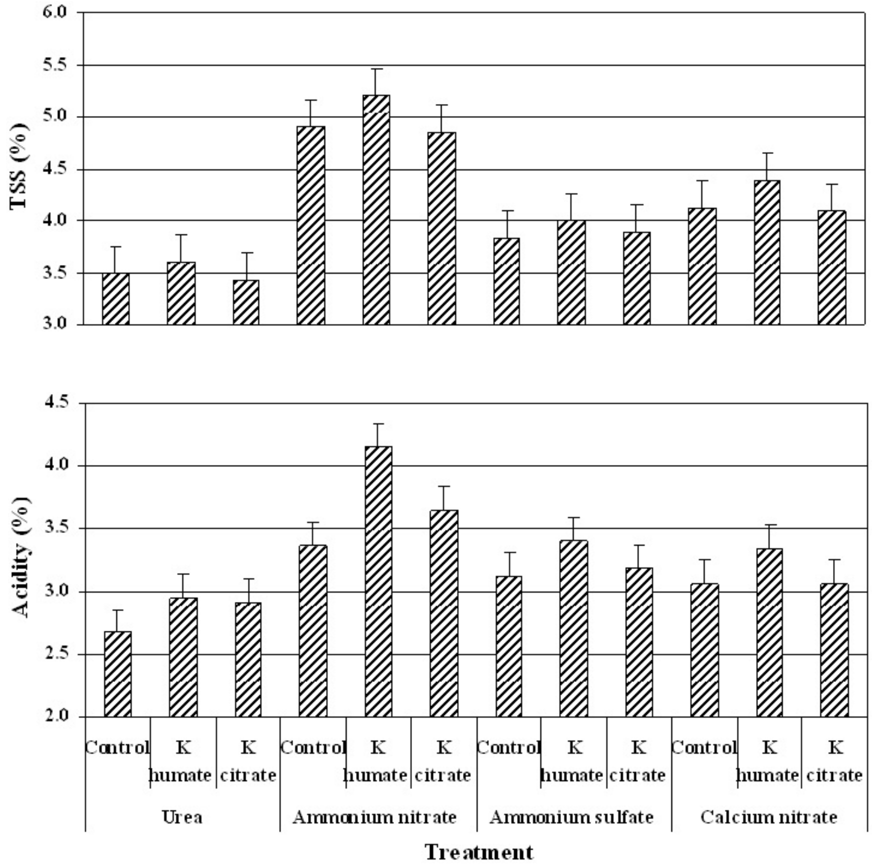

Fig. 2: Effect of nitrogen form and biostimulant foliar spray on hot pepper fruit organoleptic properities. Vertical bars present LSD value at p ≥ 5%.

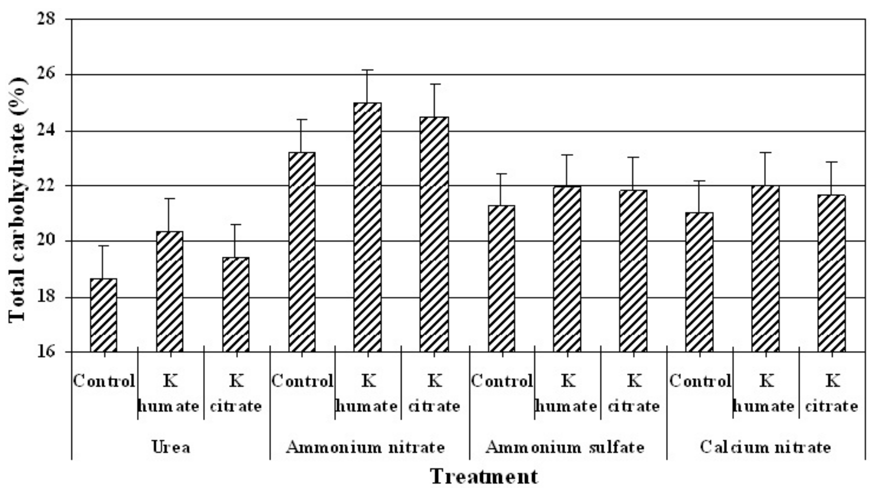

Fig. 3: Effect of nitrogen form and biostimulant foliar spray on content of total carbohydrates hot pepper fruit. Vertical bars present LSD value at p ≥ 5%.

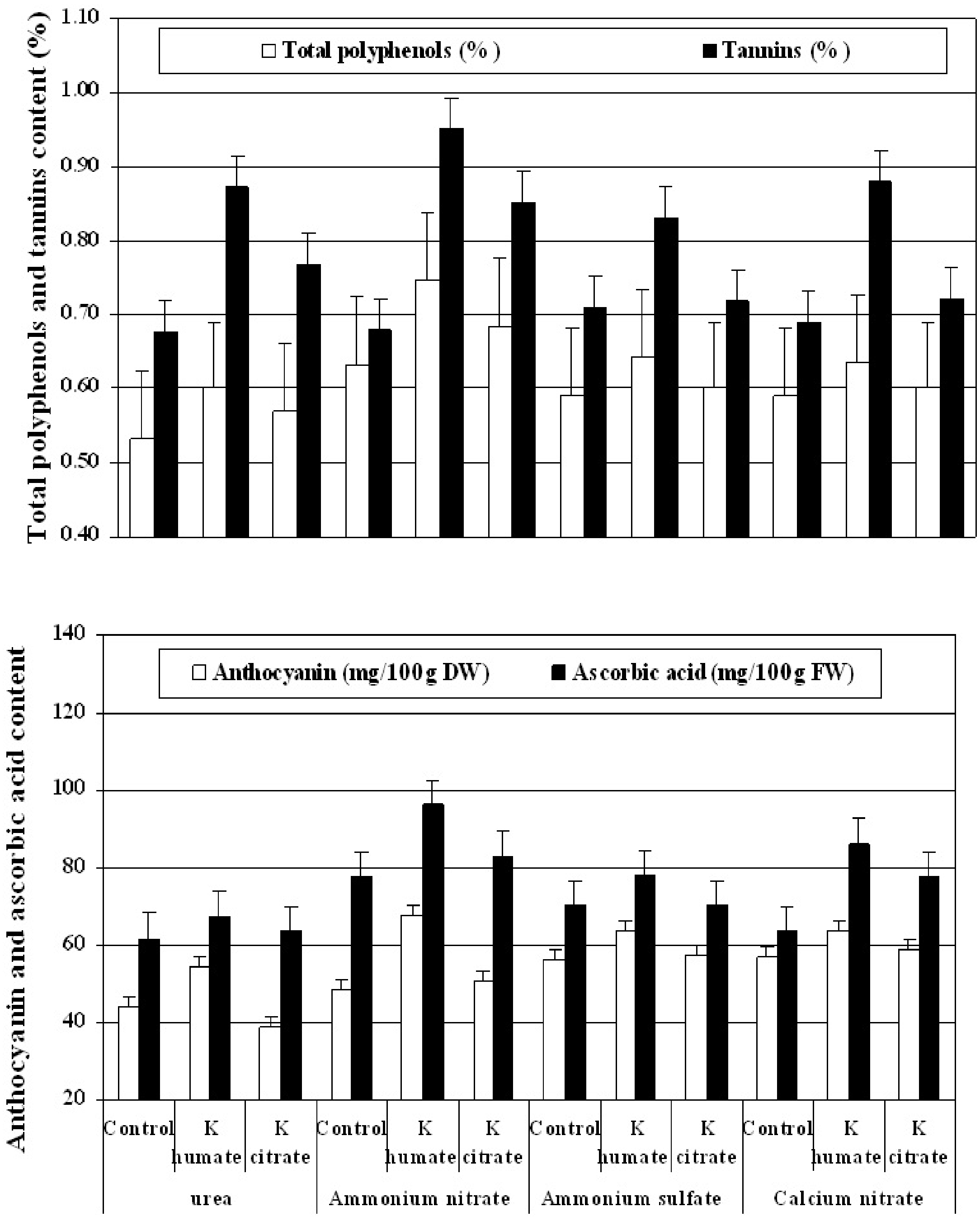

Fig. 4: Effect of nitrogen form and biostimulant foliar spray on hot pepper fruit content of total polyphenols, tannins, anthocyanin, and ascorbic acid hot pepper fruit Vertical bars on each series present LSD value at $p \geq 5\%$.

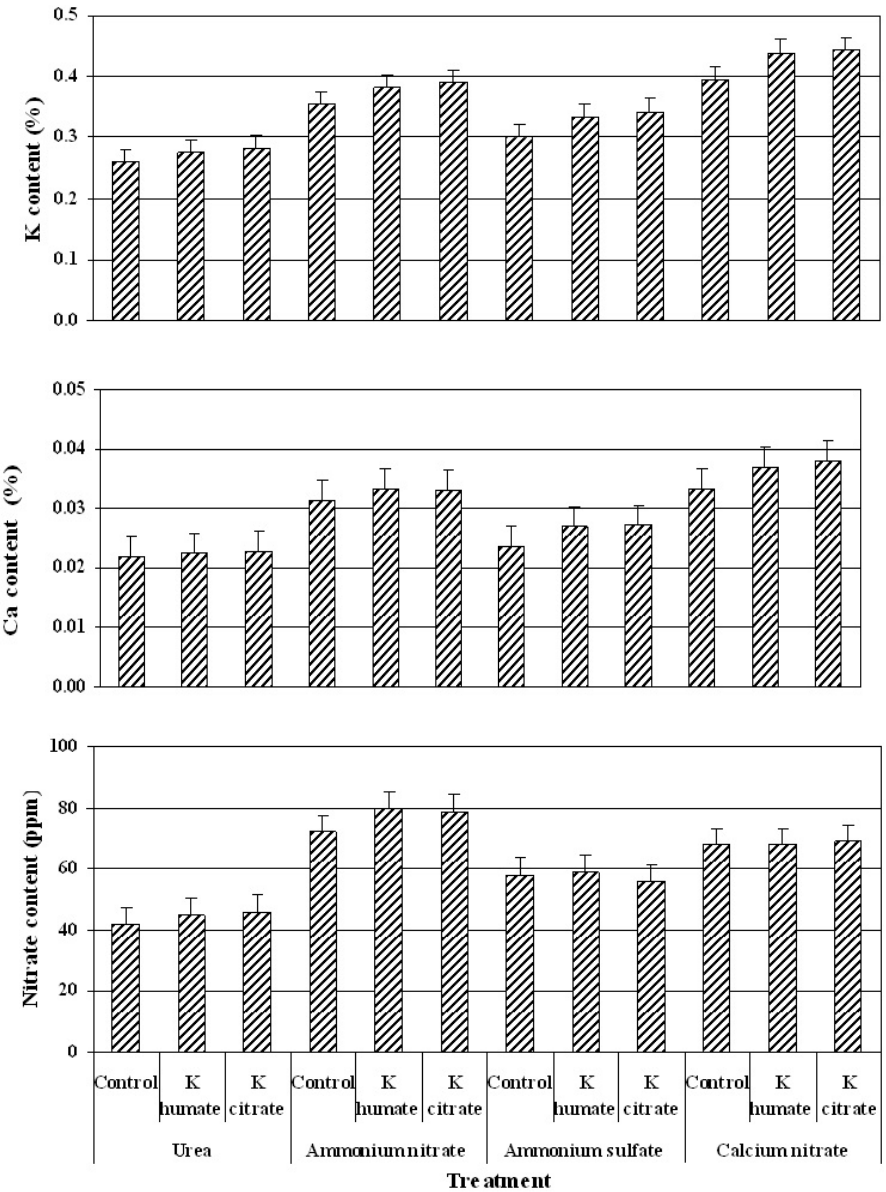

Fig. 5: Effect of nitrogen form and biostimulant foliar spray on mineral content of hot pepper fruit. Vertical bars present LSD value at $p \geq 5\%$.

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