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The Role of Humate Substances in Controlling Synergism and Antagonism of Nutrients Uptake by Potato Plants

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A FIELD experiment was carried out during the two successive winter seasons of 2016 and 2017 in a clayey textured soil located at Sakha Agricultural Research Station farm, Kafr El-Sheikh Governorate to study effect of humate substances (HS) as complexes agent on NH4+, K+, Ca++ and Mg++ antagonisms on potato crop. A split plot design was used with three replicates. The main plots were assigned with three application methods: without humate substances, humate substances fertilizer coating and soil addition of humate substances with irrigation water. The sub plots were assigned with five fertilization treatments N, NK, NKCa,NKMg and NKCaMg. The results showed that soil addition of humate substances with NKCaMg treatment had a significant effect on plant growth parameters in leaves at 90 days age and yieldcomponents. The highest values of tubers yield, dry matter of tuber, protein percent, starch percent, N, P, Mg-content were obtained with soil addition of humate substances+NKCaMg. The highest K-content was obtained with soil addition of HS+NK treatment, the highest Ca-contentwas observed with soil addition of HS+NKCa treatment. It could be concluded that humate substances fertilizer coating by humate substances or soil addition of humate substances could help in decrease antagonism process to improve plants growth and increase tubers yield and their quality under this conditions as well as increase nutrient efficiency of potato.

Keywords: Nitrogen, Potassium,calcium, Magnesium, Humate substances, Antagonisms, Clay soil, potato, Nutrient uptake, Fertilizer use efficiency

Introduction

Potato (*Solanum tuberosum* L.) is a major food crop in many countries, ranking fourth among the world's various agricultural products in production volume, following wheat, rice and corn (John 2017). The amount of available essential nutrients is the main factor of potato production Nitrogen plays a pivotal role in the plant metabolism and its growth (Muleta and Aga 2019). Potassium is that mineral which is needed in the largest amount by the potato plant which is unlike the specific nutrient requirements of most other vegetable crops. Out of all the macronutrients, potassium (K) has the highest concentrations in potato tubers (White et al. 2009). In the remaining plant tissues, it is also the most abundant inorganic cation in potato leaves. Beside this, K is one of the most important nutrients affecting potato tuber quality (Zörb et al. 2014). Potassium can reduce the susceptibility of potato to black spot bruise, decreased the occurrence of darkening after cooking, and lower tuber sugar content. It also allows the crops to adapt to environmental stress viz. salinity stress (Akram et al. 2009) and water stress (Kanai et al. 2011).It facilitates cell and root elongation (Song et al. 2017), plant movements such as stomata opening and leaf movement (Ahmad and Maathuis 2014).

Calcium is an essential part of plant cell wall; it forms calcium bectate compounds which give stability to cell walls and bind cells together; helps in protecting the plant against heat stress- calcium improves stomata function and participates in induction of heat shock proteins; participates in enzymatic and hormonal processes helps in protecting the plant against diseases; affects fruit

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quality; has a role in the regulation of the stomata (Mengel and Kirkby, 2001). Calcium (Ca) is essential for the potato crop mainly due to its role in cell wall and membrane stabilization (White and Broadley 2003 and Ozgen et al., 2003). Fertilization with calcium increases tuber calcium and lowers incidence of physiological disorders such as internal brown spot, hollow heart and bruising, as well as tuber calcium is important for the health of the sprout and of the tuber skin (Palta 2010 and Hamdi et al., 2015)

Magnesium plays a primary role in photosynthesis, protein synthesis and activator for a huge number of enzymes (Senbayram et al. 2015 and Verbruggen and Hermans, 2013). Magnesium (Mg) is a very important element in potato nutrition system. It acts as an activator for many enzyme systems involved in carbohydrate metabolism and synthesis of nucleic acids and helps in translocation of sugar (Zengin et al., 2008 and Koch et al. 2020).

The competition of cations for uptake is a well-known phenomenon (Marschner 2011; Chen and Ma 2013 and John 2017). One of the most commonly observed phenomena based on cation antagonism is K-induced Mg deficiency. Under high available K concentrations in the soil solution Mg uptake can be blocked while K uptake can be advantaged by Mg transporters (Gransee and Führs 2013).Antagonism is common among Ca++, Mg++ and K+. Cation-cation interactions occur at the membrane level and are primarily of a competitive nature called cation antagonism. When nutrients in combination results in a growth response that is less than the sum of their individual effects, the interaction is negative(Sumner and Farina1986 and Tavakkoli et al., 2015).

Humate substances (HS), which include humic acid and fulvic acid, are among the most complex and biologically active organic matter compounds in the soil and are known to stimulate both plants through a number of mechanisms (Canellas et al. 2014 and Ekin 2019). Humate substances have a positive effect on soil physicochemical properties, and soil microbial community activity and structure, resulting in availability of higher nutrient content for plant growth, furthermore but it was also demonstrated that they positively influence root growth, especially lateral root emergence and root hair initiation, involved in plant nutrient uptake (Canellas et al. 2014 and Puglisi et al. 2013). Humate substances can interact with root organic acid exudates to influence the root area, primary root length, the number of lateral roots, and lateral root density (Canellas et al. 2008 and Mosa 2012). Humic acid is a naturally-available substance in the soil and a bio product of organic matter decomposition, which was successfully used in cultivation of various crops. Direct effects of HA on plant growth were well described; these effects include enhanced macronutrient and micronutrient uptake and root growth (Xu et al. 2015). Also, the use of HA was successfully demonstrated in cultivation of several crops, such as potato (Suh et al. 2014). Humic acid is one of the most important components of humic substances as it plays a crucial role in regulating carbon cycles and catalyzing relevant redox reactions in various ecosystems (Liu et al. 2017 and Zaho et al. 2019). It is widely accepted that quinone moieties, as well as other redox-active functional groups in the HA, have an important role in electron shuttling process, thereby affecting microbial electron transfer onto Fe (III) (Stern et al., 2018). Application of HA beside different potassium fertilization levels led to increase potassium concentration in potato tubers (Awad and El-Ghamry 2007).

However, the objectives of this study are to study the possibility of using humate substances for decreasing antagonism between K and N with Ca and Mgby potato.Assess the effect of humate substances on improving plant growth, tuber yield,nutrient contents and tubers quality of potato. Evaluate the efficiency of two different addition methods (i.e., fertilizer coating and soil addition of humate substnaces with irrigation water on yield quality and nutrient contents of yield potatoes).

Materials and Methods

A field experiment was carried outduring the two successive winter seasons of 2016 and 2017 in a clayey textured soil (Clayey, Smectitic, Superactive, Mesic, Typic) located at Sakha Agricultural Research Station farm, Kafr El-Sheikh Governorate, Egypt (30o56N latitude and 31o 05 E longitude) to study the role of Humate substances to decrease the antagonisms process between N, K, Ca and Mg which affected on plants growth, yield and its quality, nutrients concentrations and uptakes of potato crop (c.v. spunta). A split plot design was used in three replicates. The main plots were assigned with three application methods of humate substances (HS):

a- Without humate substances.
b- Fertilizer coating by humate substances.
c- Soil addition application with the irrigation water.

The sub plots were assigned with five treatments of fertilizers (recommended dose) according to shown in Table 1.

TABLE 1. Mineral fertilizers, forms, recommended dose kg fed-1 and time of fertilization

Mineral fertilizers	Forms of fertilizer	Recommended dose kg fed^{-1}	Time of fertilization
Nitrogen	Ammonium nitrate (33.5%N)	150 kg N fed^{-1}	Three times(20 % with planting and 80 % at two equal doses before the first and second irrigations)
Potassium	Potassium sulphate (48% K_2O)	48 kg K_2O fed^{-1}	One dose with the planting
Calcium	Calcium nitrate contains 17 % Ca	7.5 kg Ca fed^{-1}	two times (4 kg.fed^{-1} with 34 and 3.5 Kg.fed^{-1} with 43 days after planting)
Magnesium	Magnesium sulfate contains 10 % Mg	5 kg Mg fed^{-1}	5 kgMg.fed^{-1} (2.5 kg.fed^{-1} with 34 and 43 days after planting)

1- Mineral nitrogen fertilizer (M1).

2- Mineral Nitrogen and potassium fertilizers (M2).

3- Mineral Nitrogen, potassium and calcium fertilizers (M3).

4- Mineral Nitrogen, potassium and magnesium fertilizers (M4).

5- Mineral Nitrogen, potassium, calcium and magnesium fertilizers (M5).

Natural powder of humate substances (mixture from humic acid and fulvic acid) were coated in with applied at 0.5% of the fertilizer weight of all the fertilizer types impress Arabic glue (coating HS), and the same weight (0.5%) of the fertilizer weight of all the fertilizer types was added as a one dose with planting irrigation water in the soil application treatment.All treatments had been acquisitive Phosphate fertilizer at rate of 30 kg P2O5 fed-1 as single calcium superphosphate (15.5 % P2O5) on one dose with soil preparation. Soil samples were taken from the surface layer (0–30 cm) before soil preparation; some physical and chemical properties of soil were analyzed according to shown in Table 2. Particle size distributionwas determined according to the international piptte method. Available nitrogen of the soil was extracted by 1N potassium chloride and determined by Kjleldhl Method,phosphorus was extracted by 0.5N sodium bicarbonate and calorimetrically measured by spectrophotometer. Available Potassium was extracted by 1N ammonium acetate and measured by flame photometer. Soil pH, EC and soluble cation and anions were determined in soil past extract. All determine was according to (Buurman et al. 1997).

Potatoes (c.v. spunta) were planted in 22 October, 2016 and harvested in 2 March, 2017 in 1st season, and planted in 24 October, 2017 and harvested in 3 March, 2018 in 2nd season. After 90 days from planting date, five plants from each plot were taken randomly to measure plant height, number of leaves, leaf area and chlorophyll A, B and total chlorophyll.

- Leaves area (m2 plant-1) = Dry weight of leaves x disk area x No .of disks/dry weight of disks (Koller 1972).

- After 130 days from planting date, tuber weight (g plant-1), number of tubers plant-1, fresh tuber yield (Mg fed-1), (dry matter %, starch% and protein%) were recorded.

- Starch % = (17.547+ {0.89 x (dry matter-24)}). Was determined according to Burton (1948)

- Protein% according to Ranganna (1977).

Samples of leaves and tubers that taken at harvest were oven dried at 70oC till constant weight, then ground to a fine powder and sub samples of 0.5 g were digested using a mixture of sulfuric and perchloric acidsto determine of nitrogen, phosphorus, potassium, calcium and magnesium according to A.O.A.C. (1990).

The statistical analysis of the obtained data was done according to the methods described by Gomez and Gomez (1984). The differences between the means of different treatment were tested using (L.S.D) at 5% level of probability were used to compare between treatments means.

Data in Table 3 show that application of HS increased significantly vegetative growth parameters as plant height (cm), leaves numberplant-1, leaf area (m2plant-1). The highest values of plant height (46.74 and 47.92 cm), leaves number (22.46 and 23.46) and leaves area (0.246 and 0.255m2) were obtained with the addition of HS with the irrigation water, followed by addition of HS coating of the fertilizer. On the other hand, the lowest values were recorded with the control.

TABLE 2. Some physical and chemical properties of the surface (0-30 cm) of the experimental soil at 2016 and 2017 seasons

Seasons	Particle size distribution (%)			Texture class	pH^*	EC^{**} dS m^{-1}	O.M (g 100 g^{-1})	$CaCO_3$ (g 100 g^{-1})	SAR
	Sand	Silt	Clay						
2016	18.10	30.42	51.48	Clayey	7.79	3.22	13.5	25.1	9.54
2017	17.92	32.23	49.85	Clayey	7.85	3.25	13.8	25.3	9.58

Seasons	Soluble cations and anions (mmol L^{-1})								Available NPKCaMg (mg kg^{-1})				
	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	N	P	K	Ca	Mg
2016	6.72	3.78	22.50	0.45	N.D	2.05	16.56	14. 84	29.63	5.35	258	347	205
2017	6.83	3.91	22.2	0.50	N.D	2.00	14.93	15.03	30.75	5.92	256	350	210

The interaction between humate substances and mineral fertilizerssignificantly affectedpotato growth parameters. The highest value of plant height (60.6 cm), leaves No. (25.0) in the first season and leaves area (0.294 and 0.322 cm2plant-1) were obtained with (M5) HS before the irrigation in both seasons, followed by (M5) with coating fertilizer with HS this may be due to HS decrease antagonism between K, Ca and Mg. High K levels induce Ca and Mg deficiencies.

These results agree with those obtained by Seyedbagheri (2010), Mosa (2012) and Ekin (2019) who found that a highly significant increase in potato growth when administered with humic acids. These could be attributed to role of HS of complexing the fertilizers cations on the effective groups increased humate-fertilizers efficiency. Kononova (1966) stated that HA contents of COOH, phenolic OH and total carbonyl groups were relatively high; however, the alcoholic OH groups content were low.

Plants were fertilized by (M5) treatment gave the highest values of the plant height (56.92 and 57.82), leaves No.plant-1 (23.55 and 24.22) and leaves area (m2plant-1) (0.277 and 0.289) in the first and second season respectively, in comparison with the control treatments (M1) which could be attributed to the role of K which consider a major determinant of growth parameters, Potassium is important to potato, as it strengthens stems improve nitrogen efficiency, regulates the osmotic turgor of the cells and the water balance, these results agree with Akram et al. (2009) and Kanai et al. (2011).

Results and Discussion

Vegetative growth parameters

Data in Table 3 show that application of HS increased significantly vegetative growth parameters as plant height (cm), leaves numberplant-1, leaf area (m2plant-1). The highest values of plant height (46.74 and 47.92 cm), leaves number (22.46 and 23.46) and leaves area (0.246 and 0.255m2) were obtained with the addition of HS with the irrigation water, followed by addition of HS coating of the fertilizer. On the other hand, the lowest values were recorded with the control.

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Magnesium plays a primary role in photosynthesis, protein synthesis and in the activation of various enzymes. Also, Ca plays an important roles in plant: promotes proper plant cell elongation ; participates in metabolic processes of other nutrients uptake; strengthen cell wall structure- calcium is an essential part of plant cell wall; it forms calcium bectate compounds which give stability to cell walls and bind cells together; helps in protecting the plant against heat stress. Also, these results agree with Mengel and Kirkby (2001). Increasing calcium in plant enhances plant tissue resistance to bacterial phyto-pathogens Arvin et al.(2005). Also, Ca content in the soil can influence both potato tubers number and tuber size by increasing soil Ca, one may increase average tuber size and decrease tubers number Gumede (2017). Nesreen and AbdElhady (2015) illustrated that the Ca- levels (10 and 20 kg Ca fed-1) significantly improved plant growth under Nile Delta region-Egypt

Potato yield and its components

Data in Table 4, show that application of HS significantly increased potato yield and its components as tuber fresh weight ton.fed-1, number of tubers plant-1, tuber length cm and tuber diameters cm. The highest values of tuber fresh weight tonfed-1 (15.99, 17.01), number of tubers plant-1 (9.73, 10.13), tuber length cm (13.32, 13.43) and tuber diameters (8.37, 8.45) in first and second season respectively were obtained HS added before with irrigation water.

TABLE 3. Influence of Humate substances treatments, mineral fertilizers and their interactions on potato growth parameters after 90 days from planting

Treatments		Plant height (cm)		Leaves No. plant^{-1}		Leaves area (m^2 plant^{-1})	
		1st	2nd	1st	2nd	1st	2nd
A- Humate substances treatments (HS)							
Without HS		41.31	42.48	18.26	19.06	0.222	0.225
Coated HS		44.23	44.03	20.06	20.86	0.238	0.242
Addition HS		46.74	47.92	22.46	23.46	0.246	0.255
L.S.D 0.05		**0.886**	**2.35**	**0.94**	**0.64**	**0.002**	**0.006**
F. test		**	**	**	**	**	**
B- Mineral fertilization. (M)							
M_1		28.78	30.02	17.22	18.66	0.139	0.143
M_2		35.78	36.85	19.00	19.77	0.246	0.249
M_3		45.95	45.06	20.44	21.11	0.252	0.256
M_4		53.02	54.30	21.11	21.88	0.264	0.266
M_5		56.92	57.82	23.55	24.22	0.277	0.289
L.S.D 0.05		**0.878**	**3.14**	**0.69**	**0.89**	**0.002**	**0.006**
F. test		**	**	**	**	**	**
C- Interactions between HS and M.							
Without HS	**M_1**	26.73	27.06	14.66	16.66	0.131	0.131
	M_2	32.66	34	16.33	17	0.228	0.230
	M_3	42.56	44.1	18.33	18.66	0.239	0.244
	M_4	51.03	52.56	19.00	19.66	0.253	0.256
	M_5	53.56	54.66	23.00	23.33	0.261	0.266
Coated HS	**M_1**	27.93	30	17.33	18.33	0.142	0.146
	M_2	36.20	37.40	18.66	19.66	0.252	0.257
	M_3	46.06	40.10	20.33	20.66	0.256	0.259
	M_4	54.36	55.33	21.33	22.33	0.265	0.268
	M_5	56.60	57.33	22.66	23.33	0.276	0.278

M1:recommended dose of mineral N fertilizer. M2:recommended dose ofmineral N and P fertilizer. M3:recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5:recommended dose of mineral N, K, Ca and Mg fertilizer. 1st: First season, 2nd: Second season

Plants fertilized by (M5) treatments gave the highest values of the tuber fresh weight ton.fed-1 (15.16, 17.15), number of tubers plant-1 (10.88, 11.33), tuber length(13.52, 13.67cm) and tuber diameters (9.60, 9.76cm) in the first and second season respectively. The interaction between HS with irrigation water and M5 treatment significantly increased tuber fresh weight ton.fed-1, number of tuber plant-1, tuber length cm and tuber diameters (Table 3). The highest total fresh tubers yield tonfed-1, number of tuber plant-1 tuber length cm and tuber diameters cm (17.22, 17.89 tonfed-1), (13.33, 14.00), (15.20, 15.42 cm) and (11.11, 11.25cm) in the first and second season, respectively.

This result may be attributed to the availability of Calcium which is one of the most important elements in soil and it is also a very important factor of plant growth, production potato and can influence potato tubers number, tuber size, potato crop growth and quality by increasing soil Ca (Modisane 2007, Bhattarai 2016, Zeru et al. 2017, Nauman et al. 2019 and Koch et al. 2020). Synergistic interactions which well known for N x K and N x P interactions (Aulakh and Malhi 2005). An increase in yield via various fertilizers does not lead to large increases or decreases in nutrient concentrations in potato (White et al. 2009). Also, it may be attributed to the antagonistic effect of Ca on K absorption by roots at higher levels. These results are in agreement with those obtained by Ozgen et al. (2006), Hamdi et al. (2015) and Nesreen and AbdElhady (2015).

Potato quality

Data in Table 5, show that application of HS significantly increased potato quality (dry matter, protein and starch contents). HS with irrigation water has the highest values of all parameters compared with the control treatment. Also, plots fertilized by (M5) had the highest values of dry matter, protein, starch contents in first and second season respectively, in comparison with the control treatments (M1). Application of HS withirrigation water with M5 treatment in (Table 5) significantly increased dry matter in both seasons, protein % in the first season only and starch% in the second season only. The highest values of the dry matter were (24.75, 26.42%) in first and second season respectively. These results can be led to the role of HS on chelating macro elements especially and might be decrease antagonism between K, Ca and Mg. These results could be supported with those obtained by Koch et al.(2020) who observed that, potassium is a crucial element for optimal potato production, which is unlike the specific nutrient requirements of most other vegetable crops.

Also, Mg has a pronounced role in the activation of nitrate reeducates, which is one step in the pathway responsible for nitrate assimilation into amino acid compounds (Senbayram et al. 2015). Hirschi (2004) and Arvin et al.(2005) revealed that increasing calcium in plant enhances plant tissue resistance to bacterial phyto-pathogens, and also enhances the structural of cell walls and membranes. Also these results may be attributed to role of magnesium in protein synthesis and phosphorylation processes (Zengin et al. 2008). In this respect, Talukder et al. (2009) reported that Mg fertilization significantly affected the yield and its quality.

Soil fertility after harvesting

Significant differences in soil N, P, K, Ca and Mg among HS application methods with mineral fertilizers on both seasons (Table 6). The highest values of N, P, K, Ca and Mg were (20.09, 20.45 mgkg-1), (7.13, 7.17 mgkg-1), (266.8, 268.5 mgkg-1), (345.4, 342.2 mgkg-1) and (186.6, 190.00 mgkg-1) were observed with the control (without HS) in the first and second season respectively. On the other hand, HS addition withirrigation treatments and fertilizer coated decreased the values of Ca and Mg in soil after harvesting compared with the control treatment (without HS). This may be due to increasing potato yield which led to absorb more nutrients from the soil. Concerning the effect of fertilizers on N, P, K, Ca and Mg mg.kg-1 in soil, all the combination effect of fertilizers had a significant effect on N, P,K and Mg. The highest values were obtained with (M2) treatments (18.16, 18.99 mgkg-1), (6.39, 6.48 mgkg-1) and (264, 267, 8 mgkg-1) in N, P and K mgkg-1in first and second season respectively. The highest value of Ca in soil was recorded with (M3) treatment (356, 359.11 mgkg-1), but the highest value of Mg in soil was recorded with (M4) treatment (183, 186.55 mgkg-1) in the first and second season respectively.The interaction between Application of HS and mineral fertilizers in Table 6 represents significantly effects of all parameters (available N, P and K) in the soil but no significantly effect of Ca in 2nd season only and Mg in 1st season only. The highest values were recorded due to the control treatments under non-addition of HS, while treatment with M2 gave better results under soil addition of HS in N (20.35, 21.06 mgkg-1), P (7.34, 7.45 mgkg-1) and K (274, 277 mgkg-1) in first and second season respectively.The highest values of available Mg were obtained with the control treatment (M1) with all application methods of HS but the lowest values of Mg concentration in soil was appeared with (M5) treatment under soil addition of HS These results due to chelate power of HA in soil which decreased K+ leaching (Wang and Huang 2001).

TABLE 4. Influence of Humate substances, mineral fertilizers and their interactions on potato yield and its components

Treatments	Tubers Fresh weight $ton.fed^{-1}$		Number of tubers $plant^{-1}$		Tuber length (cm)		Tuber Diameters cm	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
A- Humate substances treatments (HS)								
Without HS	14.41	**15.07**	6.60	7.13	9.19	9.32	6.62	6.69
Coated HS	14.97	**15.84**	8.46	8.86	10.89	11.02	7.78	7.90
Addition HS	15.99	**17.01**	9.73	10.13	13.32	13.43	8.37	8.45
L.S.D 0.05	**0.063**	**0.071**	**0.37**	**0.93**	**0.30**	**0.10**	**0.07**	**0.03**
F. test	**	**	**	**	**	**	**	**
B- Mineral fertilization (M)								
M_1	13.50	14.02	5.11	5.55	8.80	8.91	5.55	5.66
M_2	14.95	15.66	7.44	7.77	10.20	10.30	6.95	7.02
M_3	15.58	16.60	8.77	9.22	11.31	11.43	7.34	7.39
M_4	15.43	16.43	9.11	9.66	11.84	11.96	8.51	8.58
M_5	15.16	17.15	10.88	11.33	13.52	13.67	9.60	9.76
L.S.D 0.05	**0.07**	**0.07**	**0.52**	**0.44**	**0.16**	**0.10**	**0.10**	**0.03**
F. test	**	**	**	**	**	**	**	**
C- Interaction between HS and M								
Without HS M_1	12.32	12.52	4.00	4.66	7.00	7.06	4.43	4.53
Without HS M_2	14.58	14.63	6.66	7.00	8.53	8.63	6.13	6.17
Without HS M_3	14.97	15.88	7.33	7.66	9.10	9.23	6.50	6.52
Without HS M_4	14.84	15.74	7.00	8.00	9.06	9.26	7.86	7.93
Without HS M_5	15.36	16.59	8.00	8.33	12.26	12.4	8.16	8.31
Coated HS M_1	13.73	13.93	6.00	5.66	8.20	8.37	6.06	6.19
Coated HS M_2	14.97	15.97	7.66	8.00	10.33	10.46	7.30	7.35
Coated HS M_3	15.20	16.27	8.66	9.33	10.73	10.86	7.63	7.72
Coated HS M_4	15.07	16.10	9.33	9.66	12.11	12.21	8.36	8.51
Coated HS M_5	15.92	16.97	11.33	11.66	13.10	13.21	9.53	9.73
Addition HS M_1	14.46	15.63	6.00	6.33	11.2	11.31	6.15	6.24
Addition HS M_2	15.32	16.40	8.00	8.33	11.75	11.81	7.42	7.53
Addition HS M_3	16.57	17.67	10.33	10.66	14.11	14.21	7.89	7.94
Addition HS M_4	16.39	17.45	11.00	11.33	14.35	14.39	9.31	9.3
Addition HS M_5	17.22	17.89	13.33	14.00	15.20	15.42	11.11	11.25
L.S.D 0.05	**0.124**	**0.137**	**0.905**	**0.764**	**0.291**	**0.179**	**0.127**	**0.055**
F. test	**	**	**	**	**	**	**	**

M1: recommended dose of Mineral N fertilizer. M2: recommended dose of mineral N and P fertilizer. M3: recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5: recommended dose of mineral N, K, Ca and Mg fertilizer. 1st: First season, 2nd: Second season

TABLE 5. Influence of Humate substances, treatments, mineral fertilizers and their interactions on potato tuber quality

Treatments		Dry matter%		Protein %		Starch %	
		1st	2nd	1st	2nd	1st	2nd
A- Humate substances treatments. (HS)							
Without HS		21.56	21.624	10.53	10.98	15.37	15.43
Coated HS		22.64	22.72	11.67	12.49	15.69	16.22
Addition HS		23.91	24.64	14.28	15.00	17.43	18.12
L.S.D 0.05		**0.03139**	**0.1288**	**0.05755**	**0.3389**	**1.51667**	**0.3819**
F. test		**	**	**	**	*	**
B- Mineral fertilization. (M)							
M_1		22.21	22.28	11.39	12.15	15.95	16.00
M_2		22.41	22.51	12.09	12.58	16.13	16.22
M_3		22.61	22.91	12.26	12.78	15.20	16.30
M_4		22.99	23.36	12.45	13.21	16.62	16.97
M_5		23.29	23.90	12.60	13.39	16.91	17.46
L.S.D 0.05		**0.0451**	**0.1896**	**0.0451**	**0.2881**	**1.4621**	**0.43026**
F. test		**	**	**	**	**	**
C- Interactions between HS and M.							
Without HS	**M_1**	21.20	21.23	10.10	10.47	15.05	15.08
	M_2	21.42	21.51	10.37	10.64	15.25	15.33
	M_3	21.53	21.62	10.48	10.81	15.34	15.43
	M_4	21.72	21.76	10.73	11.39	15.52	15.55
	M_5	21.94	21.98	10.96	11.60	15.72	15.75
Coated HS	**M_1**	22.22	22.28	10.85	11.78	15.95	16.01
	M_2	22.44	22.51	11.62	12.25	16.16	16.21
	M_3	22.52	22.58	11.79	12.37	12.90	15.39
	M_4	22.85	22.90	11.98	12.91	16.63	16.56
	M_5	23.18	23.32	12.10	13.14	16.82	16.94
Addition HS	**M_1**	23.22	23.33	13.23	14.21	16.85	16.92
	M_2	23.37	23.52	14.27	14.87	16.98	17.12
	M_3	23.80	24.54	14.52	15.16	17.37	18.08
	M_4	24.41	25.41	14.66	15.33	17.72	18.80
	M_5	24.75	26.42	14.75	15.43	18.21	19.70
L.S.D 0.05		**0.078**	**0.086**	**0.328**	**-**	**-**	**0.745**
F. test		**	**	**	**N.S**	**N.S**	**

M1: recommended dose of mineral N fertilizer. M2: recommended dose of mineral N and P fertilizer. M3: recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5: recommended dose of mineral N, K, Ca and Mg fertilizer. 1st: First season, 2nd: Second season

Also, the binding power is also able to play a definite role in liberating the fixed K by expanding silicate clays (Tan 1978). Also, this is confirmed with results obtained by Thorn and Mikita (1992), using N15 and C13 NMR techniques. They detected that 15 N - labeled ammonia was incorporated into humic acid in the laboratory incubation and that the average N content of humic acid increased from 0.88 to 3.17%.On the other hand, humic acids can increase P availability by complexion with soil minerals and forming stable organic-mineral compounds, decreasing P fixation as apatite and other mineral-phosphates (Seyedbagheri 2010). Awad and El-Ghamry (2007) showed that HA increased activity of soil microorganisms and Mg availability to potato grown in an alluvial soil.

N, P, K, Ca and Mg content (kg fed-1)

Data in Table 7, shows that a significant effect of HS and mineral fertilizer content on N, P, K, Ca and Mg-content in shoot with harvest in both season. The highest values of N, P-content were (17.49, 17.61 kgfed-1) and (1.757, 1,770 kgfed-1) with (M5) treatment but when added Ca and Mg the K-content was lowed, the highest values of K-content was (36.58, 36.77 kgfed-1) with (M2) treatment.On the other hand, the lowest values of Ca-content were appeared when Mg had been added (10.47, 12.47 kgfed-1) but the highest values of Ca-content were appeared with (M3) treatment (17.35, 20.06 kgfed-1). Also, the lowest values of Mg-content was appeared when Ca had been added (1.94, 2.66 kgfed-1) but the highest values of Mg-content was appeared with (M4) treatment (3.30, 4.37 kg.fed-1) in the first and second season, respectively. These results may be attributed to N can increase P uptake in plants by increasing root growth, by increasing the ability of roots to absorb and translocate P, and as a result of absorption of NH4+ thus increase solubility of P fertilizer (Gitari et al. 2018 and Sebnie 2019) Also, there are antagonism between Ca, K. all studied observed that higher absorption of P and Ca in the lower concentrations of K is believed to be due to high mobility of K.Also, there are antagonisms between K and Ca. the decrease in Ca uptake with increasing K concentration may be related to competition between K and Ca due to physiological properties of these ions (Nesreen and AbdElhady 2015).Generally, data in Table 7 and Figs. (1 and 2) show the values of N, P, Ca and Mg-content kg.fed-1in shoot at harvest in the first and second season as affected by (HS) application with mineral fertilizers treatments. The data indicated that application of HS with mineral fertilizers had no significant effect of K-content in shoot at harvest in first season only. The highest values of N, P-content were obtained with H.S. before each irrigation water and (M5) treatment (18.40, 18.48 kgfed-1) and (1.822, 1.826 kgfed-1) in the first and second seasons, respectively. The highest values of Ca-content in shoot were indicated with of HS with irrigation water and with (M3) (21.10, 21.52 kgfed-1) in both season but the highest values of Mg-uptake were showed with soil addition of HS with (M4) treatment (4.94, 5.40 kgfed-1). The second treatment which gave a high-content values of Mg was (soil addition of HS + M5) treatment (9.55, 8.46 kgfed-1) in both season, respectively.

All these results reveal to a great role which had played by HA to decrease antagonism between elements which effect of nutrient absorption in plant. HS structure presents a variety of potential sites for binding of trace metals. Binding could be occurred through: a water bridge; electrostatic attraction to a charged COO-group; formation of coordinate linkages and ring structures; and formation of chelate structures, such as those with COO- and phenolic OH-site combinations (Shenker and Chen 2005).

N, P, K, Ca, and Mg-content in tuber at harvest

Table 8 shows the values of (N, P, K, Ca, and Mg-content) in tuber at harvest. Data show that there was significant effect of application methods of HS on N, K, Ca and Mg-content in both season, but there was non- significant effect of application of HS with the irrigation water on P-content in tuber in first season only. HS with the irrigation water gave the highest values of N, K, Ca and Mg- content (38.37, 39.09 kgfed-1), (73.74, 75.92 kgfed-1), (3.56, 3.87 kgfed-1), and (2.06, 2.27 kgfed-1) in first and second season respectively. Also, Table 8 indicated that differences between N, P, Ca and Mg-content were high significant, where the control treatment had the lowest values while all treatment gave non-significant on values of K-content in tuber in first season only. (M5) treatment had the highest N, P-content (41.00, 41.44 kgfed-1) and (9.12, 9.26 kgfed-1) in the first and second season, respectively, Compared with the control treatment while Ca-content (3.41, 3.70 kgfed-1) with (M3) treatment in 1st and 2nd season respectively. Also, Mg- content (1.95, 2.43 kg fed-1) with (M5) treatment in both season respectively, but the highest values of K-content showed with (M2) treatment in second season only 78.40kgfed-1 compared with the control treatment.Generally, data in Table 8 and Figs. (3 and 4) show values of N, P, K, Ca and Mg-content in tuber at harvest in both seasons as affected by the interaction between application methods of HS with mineral fertilizers treatments. The highest values of N and P-content were obtained with soil addition of HS + (M5) treatments (43.2, 44.10 kg.fed-1) and (10.23, 10.41 kg.fed-1) in first and second season, respectively.

TABLE 6. Influence of Humate substances, mineral fertilizers and their interactions on soil fertility after harvesting

Treatments 1st		N mgkg^{-1}		P mgkg^{-1}		K mgkg^{-1}		Ca mgkg^{-1}		Mg mgkg^{-1}	
		2nd	1st	2nd	1st	1st	2nd	1st		1st	
A- Humate substances treatments. (HS)											
Without HS		20.09	20.45	7.13	7.17	266.8	268.5	345.4	342.2	186.6	190.0
Coated HS		17.69	17.94	6.30	6.40	263.8	267.6	335.4	338.1	182.6	184.3
Addition HS		17.71	17.93	5.42	5.51	248.4	252.8	331.0	334.7	177.0	180.0
L.S.D 0.05		**0.13**	**0.05**	**0.02**	**0.09**	**1.81**	**2.81**	**1.81**	**-**	**2.61**	**1.91**
F. test		**	**	**	**	**	**	**	**N.S**	**	**
B- Mineral fertilization. (M)											
M$_1$		18.59	18.73	6.20	6.25	248.6	252.3	327.3	331.0	190.0	193.2
M$_2$		18.61	18.99	6.39	6.48	264.0	267.8	322.3	313.4	187.0	189.1
M$_3$		18.48	18.66	6.26	6.40	261.6	266.1	356.0	359.1	177.0	180.6
M$_4$		18.42	18.87	6.31	6.37	262.3	265.1	329.0	332.5	183.0	186.5
M$_5$		18.41	18.62	6.25	6.31	261.6	263.4	351.6	355.6	173.3	175.7
L.S.D 0.05		**0.10**	**0.05**	**0.04**	**0.08**	**2.00**	**1.81**	**2.00**	**14.72**	**2.58**	**1.53**
F. test		**	**	**	**	**	**	**	**	**	**
C- Interactions between HS and M.											
Without HS	**M$_1$**	20.25	20.30	6.78	6.71	253	255.3	332	335.6	196.00	
	M$_2$	20.35	21.06	7.34	7.45	274	277.0	327	296.3	193.33	
	M$_3$	20.01	20.11	7.15	7.19	267	269.3	365	367.0	187.33	
	M$_4$	20.02	20.72	7.23	7.29	270	271.0	340	345.3	193.00	
	M$_5$	19.84	20.08	7.17	7.24	270	270.0	363	366.6	183.66	
Coated HS	**M$_1$**	17.8	17.96	6.25	6.58	251	255.6	327	331.3	195.33	
	M$_2$	17.78	17.98	6.35	6.45	268	272	322	324.0	189.66	
	M$_3$	17.73	17.94	6.29	6.37	266	270.3	353	355.0	178.66	
	M$_4$	17.48	17.93	6.32	6.32	267	269.6	327	328.6	184.00	
	M$_5$	2.50	17.89	6.30	6.31	267	270.3	348	351.3	175.00	
Addition HS	**M$_1$**	17.72	17.94	5.58	5.47	242	246	323	326	188.33	
	M$_2$	17.7	17.94	5.50	5.55	250	254.6	318	320	184.33	
	M$_3$	17.7	17.93	5.35	5.65	252	258.6	350	355	176.00	
	M$_4$	17.75	17.97	5.40	5.50	250	254.6	320	323.6	182.66	
	M$_5$	17.7	17.90	5.30	5.39	248	250.0	344	349.0	168.66	
L.S.D 0.05		**0.183**	**0.092**	**0.085**	**0.145**	**3.480**	**3.135**	**3.480**	**-**	**2.655**	
F. test		**	**	**	**	**	**	**	**N.S**	**	

M1: recommended dose of Mineral N fertilizer. M2: recommended dose of mineral N and P fertilizer.
M3: recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5: recommended dose of mineral N, K, Ca and Mg fertilizer. 1st: First season, 2nd: Second season

TABLE 7. Influence of Humate substances, mineral fertilizers and their interactions on N, P, K, Ca and Mg content (kg fed-1) in potato shoots at harvest

Treatments 1st		N-content kgfed^{-1}		P- content kgfed^{-1}		K- content Kg fed^{-1}		Ca- content Kgfed^{-1}		Mg- content Kgfed^{-1}	
		2nd	1st	2nd	1st	1st	2nd	1st	2nd	1st	
A- Humate substances treatments. (HS)											
Without HS		14.17	14.34	1.460	1.480	19.65	29.76	10.44	11.08	1.26	1.92
Coated HS		15.41	15.74	1.645	1.657	32.11	32.84	15.43	15.92	3.46	3.43
Addition HS		16.63	16.75	1.716	1.732	33.34	33.62	16.59	18.18	3.60	4.00
L.S.D 0.05		**0.044**	**0.049**	**0.011**	**0.003**	**0.208**	**0.332**	**0.160**	**0.315**	**0.298**	**0.080**
F. test		**	**	**	**	**	**	**	**	**	**
B- Mineral fertilization. (M)											
M_1		12.27	12.55	1.406	1.422	23.47	23.76	14.95	15.66	2.91	3.37
M_2		13.94	14.10	1.475	1.500	36.58	36.77	12.56	13.07	2.01	2.70
M_3		16.13	16.43	1.654	1.672	26.73	33.79	17.35	20.06	1.94	2.66
M_4		17.18	17.35	1.744	1.751	27.36	34.23	10.47	12.47	3.74	4.38
M_5		17.49	17.61	1.757	1.770	27.70	31.83	16.42	19.37	3.30	4.37
L.S.D 0.05		**0.073**	**0.064**	**0.012**	**0.004**	**0.146**	**0.304**	**0.188**	**0.238**	**0.288**	**0.147**
F. test		**	**	**	**	**	**	**	**	**	**
C- Interaction between HS and M.											
Without HS	**M_1**	11.33	11.7	1.217	1.235	20.13	20.17	13.3	13.93	2.57	2.67
	M_2	12.41	12.52	1.33	1.375	35.2	35.24	8.36	8.86	0.093	1.35
	M_3	14.42	14.54	1.473	1.493	31.15	31.23	11.26	11.90	0.73	1.37
	M_4	16.18	16.35	1.629	1.636	32.50	32.45	8.26	8.20	1.79	2.38
	M_5	16.52	16.60	1.653	1.662	29.26	29.72	11.03	12.51	1.14	1.84
Coated HS	**M_1**	12.12	12.44	1.426	1.436	24.11	24.72	15.36	15.67	2.94	3.60
	M_2	14.13	14.26	1.465	1.482	36.38	36.91	12.7	12.70	3.23	2.80
	M_3	16.05	16.79	1.739	1.747	34.6	35.55	19.7	19.70	2.46	2.67
	M_4	17.21	17.45	1.790	1.798	34.3	34.78	11.24	12.64	4.49	3.38
	M_5	17.54	17.75	1.807	1.823	31.16	32.24	18.14	18.90	4.21	4.73
Addition HS	**M_1**	13.37	13.52	1.575	1.596	26.16	26.40	16.21	17.38	3.21	3.83
	M_2	15.29	15.53	1.630	1.644	38.16	38.15	13.63	14.66	2.70	2.96
	M_3	17.92	17.97	1.750	1.776	34.43	34.58	21.1	21.52	2.62	2.94
	M_4	18.15	18.25	1.813	1.819	35.30	35.46	11.91	13.58	4.94	5.40
	M_5	18.40	18.48	1.822	1.826	32.66	33.52	20.1	23.76	4.55	4.86
L.S.D 0.05		**0.127**	**0.111**	**0.021**	**0.005**	**-**	**0.527**	**0.315**	**0.412**	**0.499**	**0.134**
F. test		**	**	**	**	**NS**	**	**	**	**	**

M1: recommended dose of Mineral N fertilizer.M2: recommended dose of mineral N and P fertilizer.
M3: recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5: recommended dose of mineral N, K, Ca and Mg fertilizer.1st: First season, 2nd: Second season

TABLE 8. Influence of Humate substances, mineral fertilizers and their interactionson N, P, K, Ca and Mg content (kgfed-1) in tuber at harvest

Treatments	N-content		P- content		K- content		Ca- content		Mg- content	
1st	2nd	1st	2nd	1st	1st	2nd	1st	2nd	1st	
A- **Humate substances treatments. (HS)**										
Without HS	35.5	35.61	6.56	6.70	69.6	70.17	1.41	1.728	0.92	1.47
Coated HS	36.79	37.09	7.95	8.08	72.38	74.12	3.12	3.488	1.71	1.99
Addition HS	38.37	39.09	8.94	9.10	73.74	75.92	3.56	3.876	2.06	2.27
L.S.D 0.05	**0.041**	**0.092**	**0.026**	**0.019**	**0.071**	**0.273**	**0.032**	**0.064**	**0.021**	**0.024**
F. test	**	**	**N.S**	**	**	**	**	**	**	**
B- **Mineral fertilization. (M)**										
M_1	32.67	32.88	6.82	6.92	64.43	65.94	3.10	3.23	1.48	1.76
M_2	34.39	34.58	7.12	7.34	77.40	78.40	2.08	2.42	1.23	1.47
M_3	36.65	36.97	7.70	7.81	73.06	74.69	3.41	3.70	1.22	1.43
M_4	39.65	40.46	8.32	8.48	74.23	75.96	1.80	2.30	1.49	2.44
M_5	41.00	41.44	9.12	9.26	70.40	72.02	3.13	3.47	1.95	2.43
L.S.D 0.05	**0.037**	**0.099**	**0.021**	**0.039**	**-**	**0.240**	**0.071**	**0.114**	**0.016**	**0.038**
F. test	**	**	**	**	**NS**	**	**	**	**	**
C- **Interaction between HS and M.**										
Without HS M_1	31.21	31.31	5.92	6.07	62.00	62.03	2.50	2.55	1.22	1.38
M_2	33.20	33.40	6.03	6.23	75.10	75.63	0.88	1.21	0.64	0.92
M_3	36.08	36.17	6.58	6.66	71.00	71.83	1.70	1.91	0.65	0.91
M_4	38.23	38.36	6.88	6.97	71.70	72.36	0.80	1.26	1.03	2.00
M_5	38.78	38.83	7.39	7.57	68.20	68.98	1.20	1.68	1.05	2.14
Coated HS M_1	32.95	33.01	6.67	6.76	65.0	66.70	3.10	3.20	1.42	1.85
M_2	34.00	34.26	6.92	7.15	77.20	77.96	2.40	2.87	1.32	1.54
M_3	36.56	36.96	7.85	7.96	73.70	75.74	4.06	4.32	1.31	1.51
M_4	39.23	39.83	8.57	8.75	75.10	77.3	2.10	2.91	2.26	2.58
M_5	41.23	41.41	9.74	9.81	70.90	72.9	3.98	4.13	2.25	2.45
Addition HS M_1	33.87	34.30	7.87	7.93	66.30	69.08	3.70	3.96	1.80	2.07
M_2	35.97	36.07	8.43	8.66	79.90	81.62	2.96	3.18	1.75	1.94
M_3	37.32	37.78	8.67	8.80	74.50	76.49	4.47	4.87	1.70	1.86
M_4	41.5	43.19	9.52	9.71	75.90	78.23	2.50	2.75	2.54	2.75
M_5	43.2	44.10	10.23	10.41	72.10	74.18	4.21	4.61	2.53	2.71
L.S.D 0.05	**0.064**	**0.172**	**0.037**	**0.068**	**0.168**	**0.416**	**0.124**	**0.093**	**0.028**	**0.040**
F. test	**	**	**	**	**	**	**	**	**	**

M1:recommended dose of Mineral N fertilizer. M2: recommended dose of mineral N and P fertilizer. M3: recommended dose of mineral N, K and Ca fertilizer. M4: recommended dose of mineral N, K and Mg fertilizer. M5: recommended dose of mineral N, K, Ca and Mg fertilizer.1st: First season, 2nd: Second season

Also, data in Table 7 show the highest values of K-content in tuber with harvest show with soil addition of HS with (M2) treatment.

Data show that the highest values of Ca-content in tuber were obtained with soil addition of HS with M3 fertilizers (4.47, 4.87 kgfed-1) the second values with soil addition of HS with M5 (4.21, 4.61 kgfed-1) but values low when added (M4)fertilizers with soil addition of HS (2.50, 2.75 kgfed-1)in first and second season, respectively. Table 8, demonstrated that, the highest values of Mg-content in tuber were obtained with soil addition of HS with M4 fertilizers (2.54, 2.75 kgfed-1) the second values with soil addition of HS with M5 (2.53, 2.71 kgfed-1)but values low when added M3 fertilizers with soil addition of HS (1.70, 1.86 kg fed-1) in first and second season respectively.These results are harmony with those obtained by Allison et al.(2001), Koch et al.(2020) and Petropoulos et al.(2020), who found that increasing the N supply to the crop was often associated with an increase in the concentration of Mg in leaves and stems. This may due to N facilitating Mg uptake or a consequence of N delaying canopy senescence and, thus, delaying the translocation of Mg to tubers. Compared with the effects of N, varying the Mg and K supply to the crop had small and inconsistent effects on crop Mg uptake. Since the experiments also showed that Ca supply and soil K: Mg ratio had erratic effects on tissue Mg concentration.Gunter and Palta (2008) indicated that overall for potato production, Ca applications are recommended only if pre-plant soil exchangeable Ca is below 300 mg kg-1, and the increase in tuber Ca concentration occurred even when exchangeable Ca tested at over 1000 mg kg-1.Palta (2010) demonstrated that fertilization with calcium increases tuber calcium and lowers incidence of physiological disorders such as internal brown spot, hollow heart and bruising, as well as tuber calcium is important for the health of the sprout and of the tuber skin.Hamdi et al.(2015) showed that applying additional of calciumnitrate levels increased Ca level in leaf and tuber, but reduced the number of tubers plant-1.

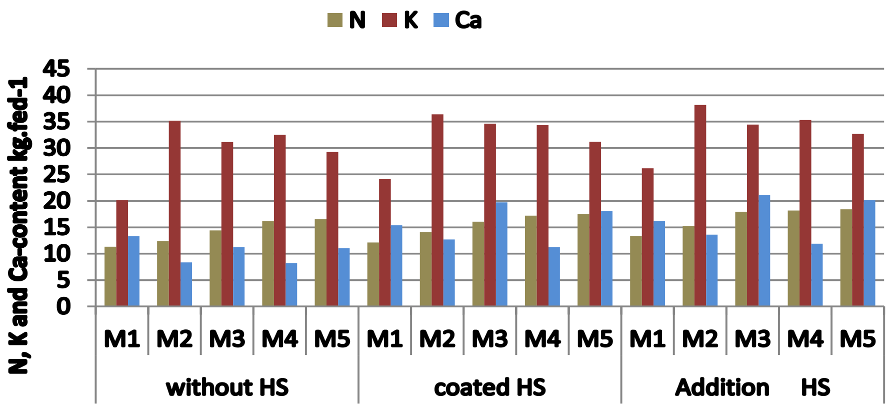

Fig. 1. Effect of the interaction between H.S and Mineral fertilizers on N, K and Ca-content shoot kg.fed-1.

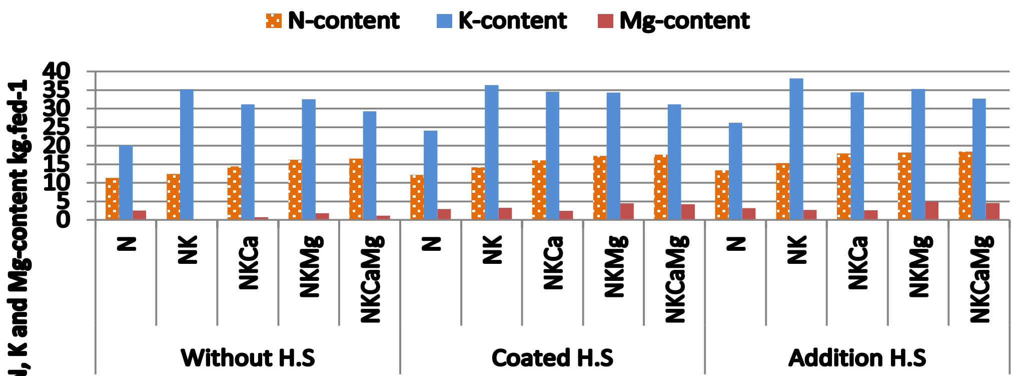

Fig. 2. Effect of interaction between H.S and mineral fertilizers on N, K and Mg-content in shoot kg.fed-1.

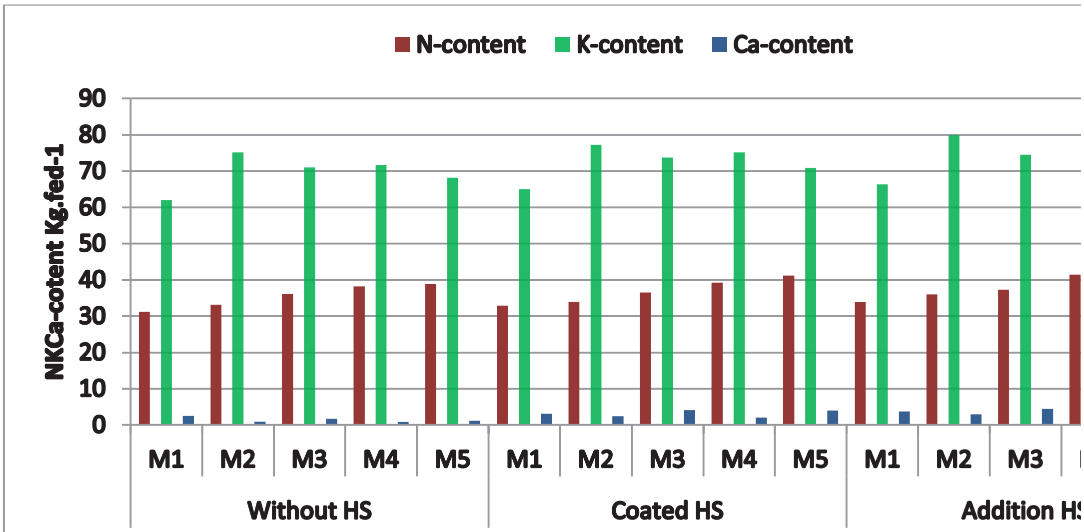

Fig.3: Effect of interactions between HS and Mineral fertilizers on N, K and Ca co (kg.fed-1) in tuber at harvest

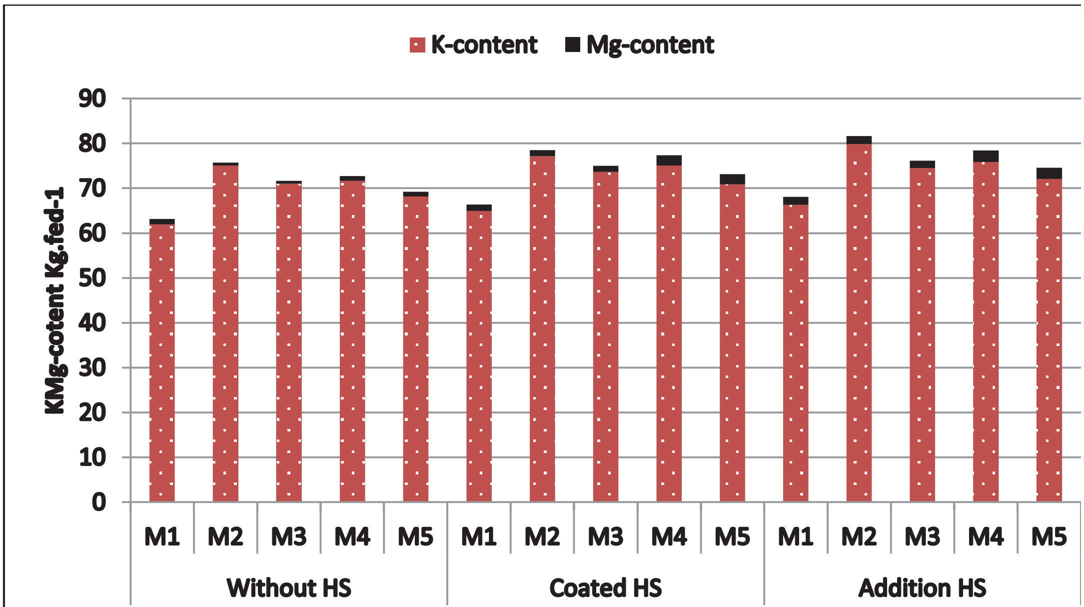

Fig. 4: Effect of interactions between HS and Mineral fertilizers on K and Mg content (kg.fed-1) in tuber at harvest

Conclusion

Soil addition of humate substances at planting irrigation water with 100% recommended dose from mineral fertilizer NKCaMg treatment increased total potato tuber yield by about 12.11% while coated fertilizer by HS with RD from NKCaMg treatment led to increase in potato production of 3.64% when compared to the control treatment. Soil addition of humate substances with recommended mineral fertilizer NKCaMg could decrease antagonism between K and N with Ca and Mg. Also, it improved plant growth, tuber yield, nutrient contents and tuber quality of potato which led to humate substances interact with (chelate) calcium, magnesium and others in soil they form new type of compounds which insoluble in water unlike potassium.

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