Effect of Potassium Humate Application on Yield and Nutrient Uptake of Maize Grown In a Calcareous Soil

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ABSTRACT

Potassium humate (K-humate) is a promising natural resource to improve yield and nutrient uptake by crops. A field experiment was conducted to assess the efficacy of K-humate application in combination with chemical fertilizers on enhancing yield and nutrient uptake of maize grown in a calcareous soil, western of Nile Delta, Egypt in two successive summer seasons (2015 and 2016). The K-humate was applied at a rate of 15 kg ha^{-1} along with an increasing rate of chemical N, P and K fertilizers, varying from 0 to 125% of the recommended dose. The results indicated that grain yield of maize significantly responded to application of K-humate. The results also indicated that the computed optimum grain yield of 7463 kg ha^{-1} without application of K-humate can be obtained by applying 98% of the recommended dose of chemical fertilizers. However, in the presence of K-humate, the optimum yield of 8310 kg ha^{-1} can be obtained by applying about 73% of the recommended dose of fertilizers. Nutrients uptake responded linearly to the increasing rates of chemical fertilizers, without or with K-humate application. However, the rate of increase in the presence of K-humate was substantially higher than that recorded at its absence. The difference in the increase of nutrients uptake was the highest for P, then N and K in the presence of K-humate. This study suggests that K-humate has the potential to increase crop yield, nutrient uptake and reduce the amounts of applied chemical fertilizers in calcareous soils.

Key words: K-humate, maize, nutrient uptake, calcareous soil

INTRODUCTION

Agriculture in Egypt is going to witness a very delicate balance between inputs and outputs of fertilizers. The demand for enough food will require substantial fertilizers inputs. But to ensure minimal leakage of fertilizers from agriculture to other ecosystems, fertilizer-use efficiency must be increased. Maize (*Zea mayes* L.) only consumes 22.5% of total nitrogen (N), phosphorus (P) and potassium (K) fertilizers used in Egypt (Heffer, 2013), representing the largest fertilizer consuming crop. An alternative solution to increase fertilizer-use efficiency is by applying materials to the soil like humic substances.

Potassium humate (K-humate) is a natural material that can improve soil physical and chemical properties and nutrient dynamics (Kumar et al., 2013; Abd-All et al., 2017). Humic acid consist on reactive functional groups with pH dependent properties, including carboxyls, phenolic, and alcoholic hydroxyls (Alvarez-Puebla et al., 2005). The effects of humic materials on plant growth are well reported in many studies (Chen and Aviad, 1990; Fagbenro and Agboda, 1993; Ihsanullah and Bakhashwain, 2013). The enhancement in nutrient uptake due to applying humic materials was also reported in numerous studies (Chen and Aviad, 1990; David et al., 1994; Kamh and Hedia, 2018).

Humic substances enhance membrane permeability, enzyme activities, hormonal activity in plant and water holding capacity, therefore increasing plant yield and nutrient uptake (Nardi et al**.** 2002; Jones et al., 2007). Sharif et al, (2002) found substantial increases in shoot and root weight of maize by application of humic materials. Also, Nandakumar et al, (2004) found that application of K-humate in combination with N, P and K chemical fertilizers increased availability of soil nutrient at different growth stages of rice.

Relatively poor productivity of maize in calcareous soils of Egypt is linked with low nutrient availability due to high $CaCO_3$ content in soil and low soil organic matter. Hence this study was performed to investigate the effect of K-humate application combined with varying rates of chemical N, P and K fertilizers on yield and nutrient uptake in maize grown in calcareous soils.

MATERIALS AND METHODS

The experimental site

Field experiment was performed in a calcareous soil at Mariout Research Station, Desert Research Center, located in Northwest of Nile Delta of Egypt during 2015 and 2016 summer seasons. Soil samples were collected before conducting the experiment and analyzed for soil properties (Table 1). Particle size distribution was conducted on soil samples using the pipette method (Page et al., 1982). Electrical conductivity (EC) and pH and were measured in soil paste (Page et al., 1982). Soil organic carbon was determined using the method of Walkely and Black (Page et al., 1982). Total calcium carbonate ($CaCO_3$) was measured using calcimeter (Page et al., 1982). Available N was extracted by 2 M KCl solution (Dahnke and Johnson, 1990) and available P and K were extracted by 1 M NH_4HCO_3 in 0.005 M

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Table 1. Some physical and chemical properties of the surface soil (0-30 cm) of the experimental site

Season	Texture	pH*	EC** dS m^{-1}	$CaCO_3$, %	Organic matter, %	Avail. N, mg kg^{-1}	Avail. P, mg kg^{-1}	Avail. K, mg kg^{-1}
Season 1	Sandy loam	8.2	4.51	30.5	0.86	73.4	9.9	244
Season 2	Sandy loam	8.1	5.34	31.4	0.74	61.2	7.1	286

* pH in saturated soil paste. ** Electrical conductivity in saturated soil paste extract.

DTPA (Soltanpour, 1991). Nitrogen was determined using micro-Kjeldahl, P colorimetrically using spectrophotometer and K using flamphotometer (Page et al., 1982).

Treatments and experimental design

The experiments were arranged in a split-plot design with three replications. Main plots were assigned for K-humate as with and without application. The rate of K-humate was 15 kg ha^{-1} which applied at sowing. Subplots were assigned to an increasing rate of N, P and K fertilizers as 0, 25%, 50%, 75%, 100% and 125% of the recommended dose. The fertilizer recommendations for maize in this region are 285, 60 and 25 kg ha^{-1} N, P_2O_5 and K_2O, respectively. The fertilizers source were ammonium nitrate (33.5% N), single superphosphate (15% P_2O_5) and Potassium sulphate (48% K_2O).

Crop management and analysis

In both seasons, maize (*Zea mayes* L.) was sown during the last week of May using triple-cross hybrid 321 variety. Experiments were irrigated almost once every week. At maturity, maize was harvested and samples from grain and stover were collected. Plant samples were washed by distilled water, dried at 70 ?C for 72 hrs in a hot air oven, and then ground. The ground samples were wet digested in H_2SO_4 - H_2O_2 mixture (Karla, 1997) for N, P and K analysis.

Data analysis

The analysis of variance (ANOVA) was performed to determine the effects of treatments on the obtained data (Gomez and Gomez, 1984). The difference between means at probability level of 0.05 was conducted using least significant difference test (LSD). Excel software was used for the purpose of calculations and fitting curves.

RESULTS AND DISCUSSION

Effect of K-humate on grain yield of maize

Grain yield of maize significantly increased with the increase of fertilizer rates without and with K-humate application (Table 2). The highest grain yield without application of K-humate was 7650.1 kg ha^{-1} that recorded at 125% of chemical fertilizer application rate without K-humate application in the first season. However, 100 and 125% of the recommended rates were the best treatments in comparison with others in the second season. On the other hand, application of K-humate gave the highest significant grain yield at 100% and 125% of the recommended dose of fertilizers with value ranging from 8450.4-8525.3 kg ha^{-1} in the first season. Application of K-humate along with 75%, 100% and 125% of the recommended dose of fertilizers gave grain yield ranging from 8367.2-8744.6 kg ha^{-1} that were statistically at par and higher than the other treatments in the second season. These results agree with the results of Eyheraguibel (2004) who reported that humic substances improved the vegetation growth of maize. Furthermore, Sharif et al. (2002) conducted a pot experiment on maize and found a significant increase in shoot and root weight of maize by applying humic materials.

The increasing rate of chemical fertilizers without or with application of K-humate resulted in grain yield of maize following a second degree polynomial function (Fig. 1). The maximum computed grain yield, without application of K-humate, was obtained by derivative analysis of the second degree equation to be 7856 kg ha^{-1} at about 140% of the recommended dose of fertilizers. However, in the presence of K-humate, maximum grain yield was computed to be 8747 kg ha^{-1} at about 103% of the recommended dose of fertilizers. The optimum yield is always lower than the maximum yield for the economical consideration. Therefore, at 95% of the maximum yield, it is predicted that optimum grain yield of 7463 kg ha^{-1} without application of K-humate can be obtained by applying 98% of the recommended dose of fertilizers. However, with the presence of K-humate, the optimum yield of 8310 kg ha^{-1} can be obtained by applying about 73% of the recommended dose of fertilizers. These findings infer that higher grain yield of maize can be achieved with saving of about 25% of fertilizers by applying K-humate.

Effect of K-humate on nutrient uptake

The highest significant N, P and K uptake by maize at both seasons was recorded by applying 125% of the recommended dose of fertilizers without and with application of K-humate (Table 2). However, the amounts of nutrient uptake with application of K-humate were markedly higher than that recorded at its absence. That seems to be logic since plants tend to uptake nutrients when present in soil in surplus amount, but does not necessary reflected on yield (Marschner, 2011).

The relation between chemical fertilizers rate and N, P and K uptake without and with application of K-humate are shown in Figs. (2-4). Nutrients uptake responded linearly to the increasing rate of fertilizers. However, the increasing rate in the presence of K-humate was substantially higher than that observed at its absence. Uptake efficiency was assessed by finding the first derivation (*dy/dx*) of the linear equations (Table 3). The efficiency coefficients for N, P and K uptake without application of K-humate were 195.43, 21.7 and 96.01, respectively. These values were increased to 149.35, 30.88 and 105.83, respectively in the presence of K-humate. The differences in the increase of uptake from high to low were for P uptake (46.6%), N uptake (27.6%) and then K uptake (10.2%).

Table 2. Grain yield and total nutrient uptake by maize as affected K-humate application and chemical fertilizer dose in the two studied seasons

Treatment		Grain yield ($kg\ ha^{-1}$)	Total N uptake ($kg\ ha^{-1}$)	Total P uptake ($kg\ ha^{-1}$)	Total K uptake ($kg\ ha^{-1}$)
		First season			
Without HA	NPK_0	2475.2 f *	75.3 f	10.3 e	51.1 f
	$NPK_{25\%}$	4650.4 e	145.2 e	18.3 d	98.4 e
	$NPK_{50\%}$	5450.4 d	187.9 d	24.0 c	114.3 d
	$NPK_{75\%}$	6650.4 c	235.4 c	27.5 bc	139.2 c
	$NPK_{100\%}$	7250.5 b	295.0 b	31.1 b	162.1 b
	$NPK_{125\%}$	7650.1 a	318.3 a	38.4 a	175.5 a
With HA	NPK_0	3325.1 e	94.9 f	15.4 f	69.3 f
	$NPK_{25\%}$	5600.2 d	177.7 e	23.3 e	117.4 e
	$NPK_{50\%}$	7315.2 c	215.4 d	30.6 d	153.4 d
	$NPK_{75\%}$	8325.3 b	300.3 c	35.7 c	175.1 c
	$NPK_{100\%}$	8525.3 a	377.6 b	44.6 b	189.9 b
	$NPK_{125\%}$	8450.4 ab	393.8 a	54.9 a	208.9 a
LSD HA ($p < 0.05$)		801.8	32.3	N.S.	19.2
LSD fertilizers ($p < 0.05$)		138.8	4.6	2.6	3.6
LSD interaction ($p < 0.05$)		645.7	25.3	10.4	15.7
		Second season			
Without HA	NPK_0	2593.7 e	74.4 f	10.7 e	52.6 f
	$NPK_{25\%}$	4808.7 d	143.7 e	18.7 d	101.8 e
	$NPK_{50\%}$	5479.1 c	189.7 d	24.6 c	116.6 d
	$NPK_{75\%}$	6842.4 b	232.9 c	28.2 bc	144.8 c
	$NPK_{100\%}$	7608.5 a	297.9 b	32.1 b	167.0 b
	$NPK_{125\%}$	7990.8 a	314.9 a	39.2 a	176.4 a
With HA	NPK_0	3439.6 d	93.9 e	16.1 e	71.3 f
	$NPK_{25\%}$	5603.1 c	175.8 d	23.3 d	119.2 e
	$NPK_{50\%}$	7569.2 b	215.4 c	31.9 c	155.6 d
	$NPK_{75\%}$	8367.2 a	294.2 b	35.5 c	178.6 c
	$NPK_{100\%}$	8643.6 a	381.4 a	46.5 b	190.8 b
	$NPK_{125\%}$	8744.6 a	391.7 a	56.2 a	206.7 a
LSD HA ($p < 0.05$)		376.0	14.2	N.S.	19.1
LSD fertilizers ($p < 0.05$)		292.2	8.3	2.9	5.9
LSD interaction ($p < 0.05$)		415.2	13.0	8.6	14.4

* Same letters within the column means there is no significant difference at 0.05 level by least significant difference test (LSD).

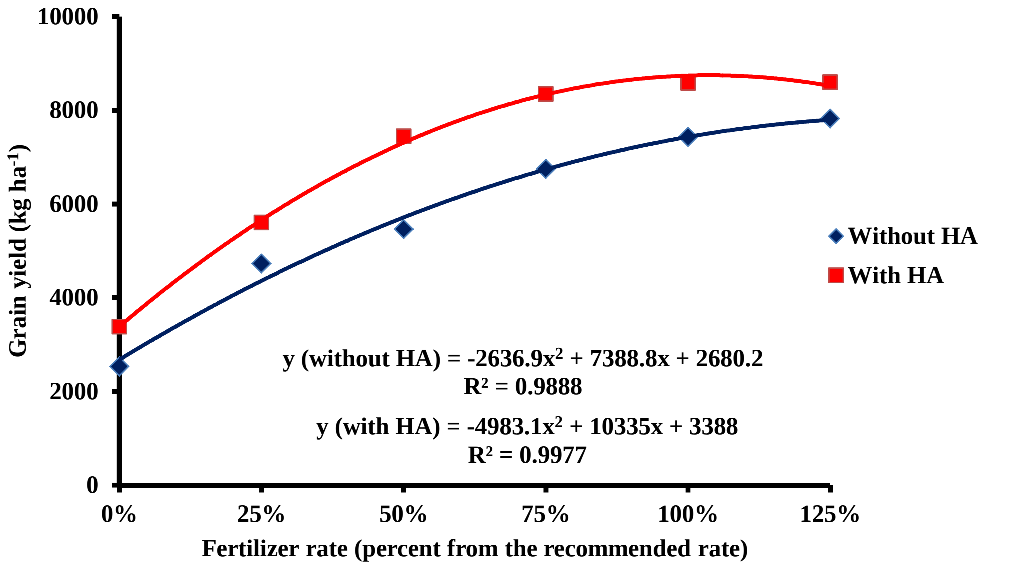

Fig. 1. Relationship between grain yield of maize and fertilizer rate with and without K-humate application

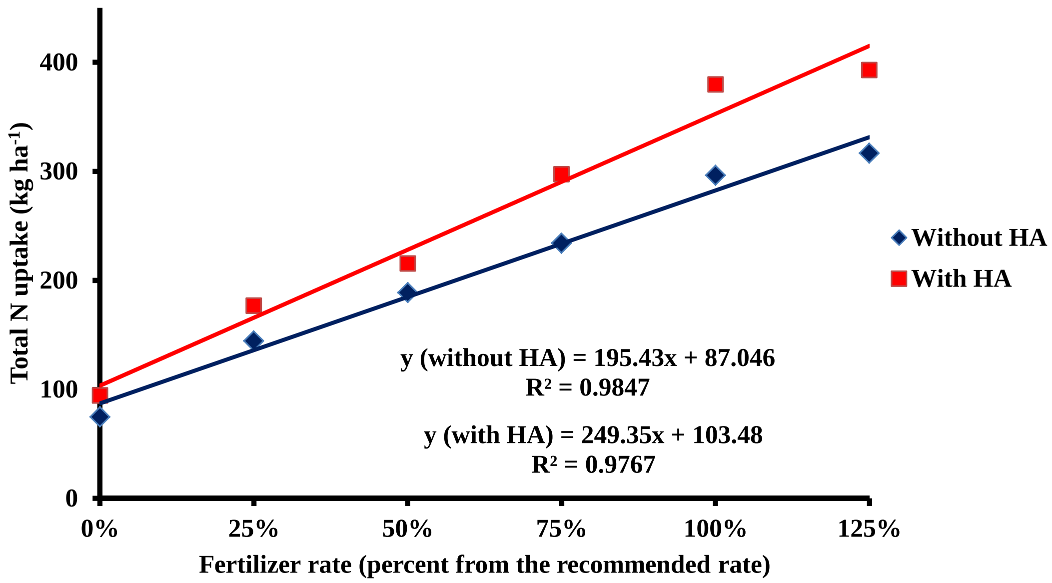

Fig 2. Relationship between total N uptake and chemical fertilizer rate with and without K-humate application

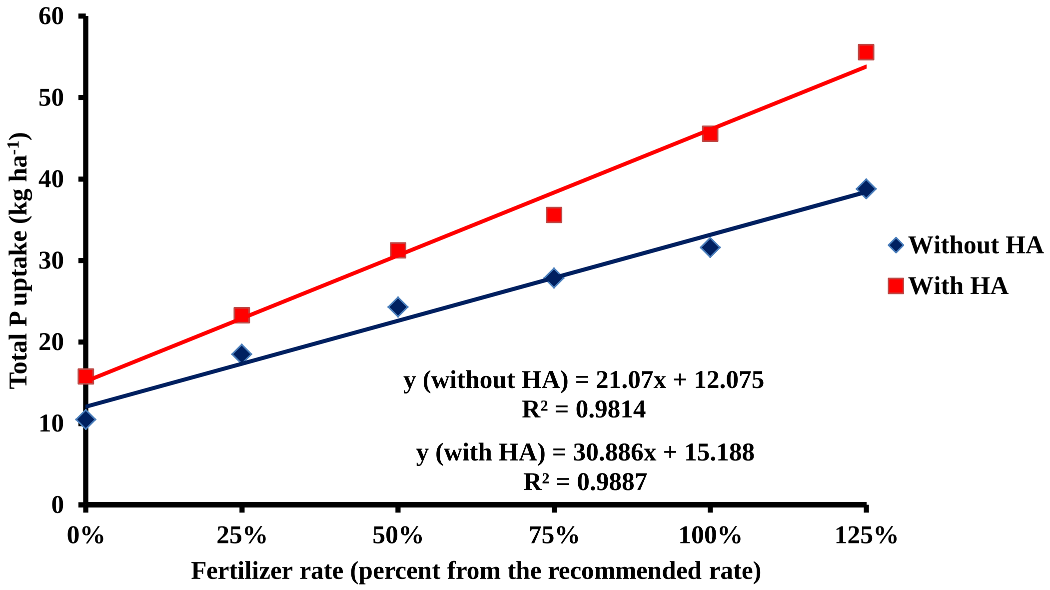

Fig 3. Relationship between total P uptake and chemical fertilizer rate with and without K-humate application

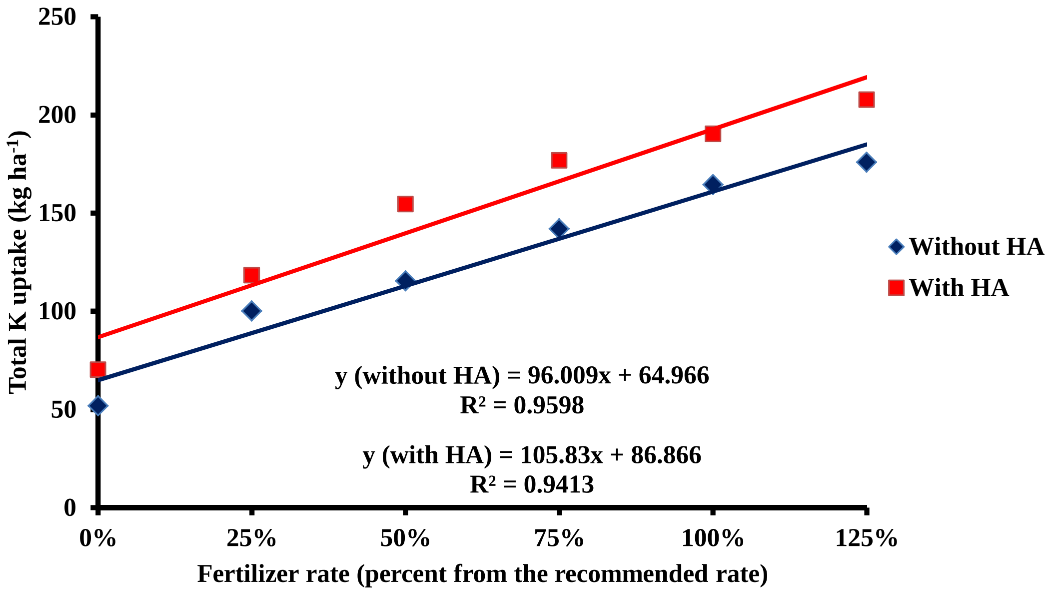

Fig 4. Relationship between total K uptake and chemical fertilizer rate with and without K-humate application

Table 3. Linear regression and efficiency coefficients for N, P and K uptake for maize in response to the increasing rate of fertilizers without and with K-humate application

Nutrient uptake	Application of HA	Linear function	Uptake efficiency (dy/dx)
N	Without HA	*Y=87.046+195.43X*	195.43
	With HA	*Y=103.48+249.35X*	249.35
P	Without HA	*Y=12.075+21.07X*	21.07
	With HA	*Y=15.188+30.88X*	30.88
K	Without HA	*Y=64.966+96.01X*	96.01
	With HA	*Y=86.866+105.83X*	105.83

The enhancement of nutrient uptake in the presence of K-humate could be due to its positive effect on membrane permeability of plants (Zientara, 1983). This is due to the presence of hydrophilic and hydrophobic sites that enhance surface activity (Chen and Schnitzer 1978). Therefore, the humic substances interact with structures of the cell membranes and react as nutrient carrier. Furthermore, root volume increases with humic substances application which considers an important factor in nutrient uptake (Canellas et al., 2002; Eyheraguibel, 2004). The highest increase in nutrients uptake in the present study was for P. This might be due to that humic acid helped in solubilizing P from insoluble to soluble form resulting in its increase. In fact, a large portion of P in calcareous soils is present in unavailable form to plants. The major mechanism involved in such soil is the increase in P availability, as reported by Delgado et al. (2002) and Satisha and Devarajan (2005), due to the interference with calcium phosphate.

CONCLUSIONS

Application of K-humate to maize grown in a calcareous soil induced positive effects on yield and nutrient uptake. In the presence of K-humate, the optimum grain yield of maize can be obtained by applying only 73% of the recommended dose of chemical fertilizers. Plant uptake of N, P and K substantially increased as well. The differences in the increase of nutrients uptake from high to low were for P, N and K uptake. In conclusion, application of K-humate can lessen the need of chemical fertilizers by about 25% and subsequently reduce environmental pollution and cost of production.

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الملخص العربي

تأثير إضافة هيومات البوتاسيوم على المحصول وإمتصاص العناصر الغذائية بواسطة نبات الذرة النامي في أرض جيرية

شريف محمود ابراهيم و علي محمد محمد علي

تعتبر هيومات البوتاسيوم مادة من مصدر طبيعي والتي يمكن إستخدامها في تحسين إنتاجية المحاصيل وزيادة وإمتصاص العناصر الغذائية. اجريت تجربة حقلية في موسمين متتابعين لتقييم فاعلية إضافة هيومات البوتاسيوم مع الاسمدة المعدنية في تحسين إنتاجية وإمتصاص العناصر بواسطة الذرة النامية في أرض جيرية، غرب دلتا النيل، مصر. حيث تمت إضافة هيومات البوتاسيوم بمعدل ١٥ كجم للهكتار مع معدلات متزايدة من الاسمدة المعدنية للنتروجين والفوسفور والبوتاسيوم من صفر الى ١٢٥% من التوصيات العامة. وقد أوضحت النتائج ان محصول الحبوب للذرة استجاب بشكل معنوي لإضافة هيومات البوتاسيوم. كذلك دلت النتائج ان المحصول الامثل للذرة تم حسابه ليكون ٧٤٦٣ كجم للهكتار بدون إضافة هيومات البوتاسيوم والذي يمكن الحصول عليه بإضافة ٩٨% من التوصيات العامة للأسمدة. بينما بإضافة هيومات البوتاسيوم، تم حساب المحصول الامثل ليكون ٨٣١٠ كجم للهكتار بإضافة ٧٣% فقط من التوصيات العامة للاسمدة. قد تحسن ايضا إمتصاص العناصر الغذائية بعلاقة خطية نتيجة إضافة المعدلات المتزايدة من الاسمدة مع او بدون إضافة هيومات البوتاسيوم، لكن معدل الزيادة في وجود هيومات البوتاسيوم كان اعلى. وقد وجد ان معدل الاختلاف في الزيادة في إمتصاص العناصر الغذائية كان اعلى للفوسفور، ثم النتروجين والبوتاسيوم في وجود هيومات البوتاسيوم. تقترح تلك الدراسة ان هيومات البوتاسيوم لها القدرة على تحسين الإنتاجية وإمتصاص العناصر الغذائية بواسطة المحاصيل، وبالتالي تقليل معدلات إضافة الاسمدة المعدنية.