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Effect of humic substances alone and in combination with micronutrients on potato yield and nutrients status

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Abstract

A field experiment was conducted at farmer field during 2014 in Sahiwal to see the combined effect of HA and micronutrients on potato yield and nutrients uptake. Experiment consists of six treatments viz full of recommended dose of chemical fertilizer (NPK), CDHA at 30 kg ha^{-1} along with one third reduced application of recomd. NPK, PDHS at 300 L ha^{-1} along with one-third reduced application recomd. NPK, CDHA@ 30 kg ha-1) along with one-third recomd. NPK+MN, PDHA (plant derived humic acid) @300 l ha-1 along with one third reduced application recomd. NPK+MN, CDHA@ 200 mg L^{-1}), Foliar along with one third recomd. NPK+MN. The experiment was planted in randomized complete block design having three treatments. The results showed that the highest yield of 23.04 t ha^{-1} obtained with the application of HA plant material @ 300 l ha^{-1} along with micronutrients followed by 22.41 t ha^{-1} with the application of coal HA @ 30 kg ha^{-1} and 21.16 t ha^{-1} with PDHA@ 300 L ha^{-1} along with micronutrients. The control treatment i.e. full NPK gave 18.86 t ha^{-1}. From the study it can be concluded that HSs increased the yield as well as saving 25% in the input cost.

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Introduction

Pakistani soils are alkaline, calcareous in nature having high pH, availability of nutrients is a major problem for good crop stand. Farmyard manure and other organic sources are not properly applied. Recommended NPK fertilizer for potato production stands to be 250:150:100 kg/ha. However, continuous trend of increase in fertilizer price triggers increase in production along with deteriorating the fertility status of the soil.

Potato (*Solanum tuberosum* L) is an important vegetable crop in Pakistan. As rich food source it is used as vegetable, and for chips, snicker and other food source. Total area under potato cultivation stands 169000 ha with production potential of 3.0 m tons (Economic survey, Pakistan, 2014-15), showing an increase of 6.3% over last year. Humic substances (HSs) benefits plant either by complexing metals due to the presence of functional groups and make nutrients available to plant (Chen *et al*, 2004), (García *et al.*, 2004) or by the presence of auxin or auxin-like compounds (Aguirre *et al.*, 2009; Mora *et al*; 2012; Jannin *et al.*, 2012). Other beneficial role include improving root and shoot functionality, both at transcriptional and post-transcriptional (Aguirre *et al.,* 2009; Mora *et al.*, 2012), and root to shoot NO_3 translocation.

Our earlier research also demonstrated that HSs improve micronutrients solubility in soils amended with HSs peas and pepper yield (Khan *et al.*, 2013a; Khan *et al.*, 2013b). A field study was conducted to evaluate the effect of co-application of HSs with either single nutrient or mixed NPK fertilizers through a drip irrigation sys-tem to potato planted in a sandy soil show that HSs significantly increased the total marketable yield of potato tubers (Selim *et al.*, 2009b). The highest marketable yield of potato tubers was obtained from the co-application of HSs with 100% of the recommended fertilization rate of NPK which is primarily attributed to the enhancement of fertilizer use efficiency which decreased the leaching of nutrients from the rooting zone, and increased plant nutrient uptake (Ezzat *et al.*, 2009) studied that K-humate application at 30 Mg ha^{-1} increased the marketable yield quantity of potato by 33%. HSs at the rate of 2 kg ha^{-1} along with Cu and Zn showing a yield increase increase wheat production in grown on salt affected soils (Manzoor *et al.*, 2014).

Previous work was done by (Susic *et al.*, 1991) where he investigated that actually Humic substances are present in all plant materials and could be extracted through dilute alkali except those bind to proteins and other with organic matters. Moreover he mentioned that this is purely a chemical process and humic substances could be prepared above the soil. He rejected the old theory of lignoprotein. According to which humic substances are formed by the decomposition of lignin through microbial masses present in the soil. Similarly humic substances were formed during composting process where about 20% humic acid was formed. Humic substances are purely organic materials improving soil chemical physical and biological properties, having no toxic effects on soil ad are cheap sources compared to chemical fertilizers. A lot of raw material is available in our country for the formation of humic substances. So we conducted this research for increasing the productivity of crops and improving soil health as a very suitable opportunity for such work to be done. All the waste plant materials could be recycled and used for increasing the organic matter content of the soil and ultimately increasing the yields and improving the soil properties. Further research is needed to identify the specific sites of activation and in this way the volume could be decreased and more area could be covered due to application.

Materials and methods

Field experiment was conducted in Sahiwal farmer field to investigate the effect of humic acid alone and in combination with micro nutrients on potato crop during 2014. There were six treatments i.e. full dose of recommended fertilizer (100% recomd. NPK), CDHA (coal derived humic acid) at 30 kg ha^{-1} along with one third reduced application of recomd. NPK, PDHS (plant derived humic acid) at 300 l ha^{-1} along with one third reduced application recomd. NPK, CDHA at 30 kg ha^{-1} along with one third recomd.

NPK+MN (micronutrients), PDHS at 300 l ha^{-1} along with one third reduced application recomd. NPK+MN, CDHA at @ 200 mg l^{-1} Foliar along with one third recomd NPK+MN. Soil composite samples were collected from two depths (0-15 and 15-30 cm) and analyzed their physico-chemical properties such as pH, Ec, P,K, etc. Potato tubers were sown in Nov, 2014 and harvested in March, 2015. Plot size was 4.5 m^2. Data was collected on tuber yield.

Standard agronomic practices were adopted. Chemical analysis containing macro and micro element analysis of tuber was also carried out.

Humic substances were derived from plant and coal materials as described in detail (M. Susic *et al*; 1991; Khan *et al.*, 2013a). The elemental composition of selected plant and coal HA extractions were carried out at Centre of Excellence Geology laboratory, Peshawar, University.

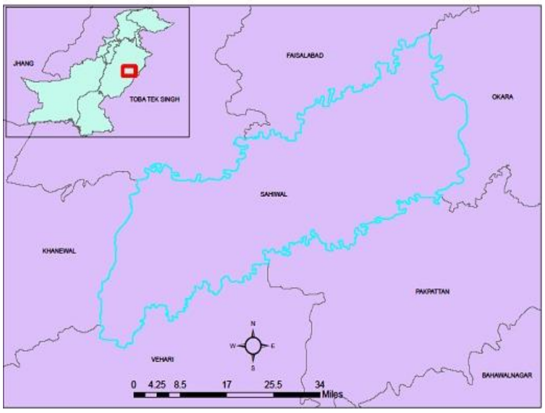

Fig. 1: Location of Experimental site

Physico-chemical properties of soil

The soil chemical properties of Sahiwal were expressed in Table 2. Soil pH and EC were determined by pH meter and EC meter respectively in 1:1 soil and Distill water ratio, total organic C was measured by wet oxidation method (Walkley and Black, 1934), available P was determined as by AB-DTPA at pH 7.6 (1:2 soil: extract ratio).

Micronutrients (Zn, Cu, Fe and Mn) were determined wit Ammonium bicarbonate diethylene triamin penta acetic acid (AB-DTPA) using atomic absorption spectroscopy (Perkin Elmer, 800).

Table 1. Physicochemical properties of soil.

Property	Unit	0-15 cm	15-30 cm
pH	1:1	8.4	8.4
EC	(ds m^{-1})	1.8	2.96
OM	%	0.42	0.03
P-ABDTPA-ext		0.04	80
K-ABDTPA-ext		85	1.07
Zn	mg kg^{-1}	1.8	1.45
Cu		2.05	6.4
Fe		7.5	0.85
Mn		1.1	

OM=Organic matter, ABDTPA= Ammonium bicarbonate diethylene triamine penta acetic acid.

Statistical analysis

Statistix 8.1 was adopted for statistical analysis. Analysis of variance (ANOVA) was used to measure the variance among the treatments, while the least significant difference (LSD) was used to compare the difference among the treatments means.

Results and discussion

Analysis of Soil and HSs

Soil properties listed in Table 1show that soil has pH 8.4 and EC <1.78 and 2.86ds/m being alkaline and saline in nature to some extent and having low 0.42%, OM. The soil has, soil is P deficient. Soil is also deficient in micronutrients (Zn, Cu, Fe and Mn).

Elemental composition of CDHSs, PDHSs (sunflower derived as SFDHSs, presented in Table 1 showed that Carbon (C) constitute over 50% followed by Hydrogen (H) as~3% and Nitrogen (N) as > 1% in all HSs derived from two sources. The Effect of humic acid alone and in combination with micronutrients on potato yield was statistically significantly indicated in Table-2.

Table 2. Effect of Humic acid on yield in potato

Treatments	Yield (t ha^{-1})	% increase over control
Full NPK	18.86^{c}	
75 % NPK+CDHA	21.02^{b}	11
75 % NPK+PDHA	21.16^{b}	12
75 % NPK+CDHA+MN	22.41^{a}	19

75 % NPK+PDHA+MN	23.04[a]	22
75 % NPK+CDHA (foliar)	20.79[b]	10

PDHA=Plant derived humic acid, CDHA=coal derived humic acid. MN=Micronutrients.

Results showed that PDHA along with MN increased the yield by 22% over the control which is similar to earlier studies (Khan *et al.*, 2013b), where the yield increases was due to application of K-humate. These results were attributed to increase membrane permeability of plants, which would promote greater nutrient uptake, and accelerate the net rate of photosynthesis by increasing the concentration of photosynthetic pigments in the plant leaves (Zhang *et al.*, 2003). Moreover it is also due to the hormone like properties of the humic acid as described [3]. According to this theory the humic substances have direct effect on plant growth due to the hormones and these effects are based on the potential presence of auxin or auxin-like compounds imbibed in HS-supra molecular-aggregated structure (Trevisan *et al.*, 2010). Similarly yield was increased due to the nutritional theory as explained earlier (Chen *et al.*, 2003) mainly based on the ability of HS to complex metals due to the presence of functional groups with chelating activity in the structure. The CDHA along with MN increased the yield 19%, while CDHA alone increased the yield by 16%. Which are similar to the results obtained by (Ezzat *et al.*, 2009). Foliar application increased the yield by 8%.

The chemical composition of tuber was depicted in Table 3. The tuber analysis show that the maximum P content was 0.388 mg kg^{-1} in CDHA applied along with MN which is similar as reported earlier (Samson *et al.*, 1989) where P concentrations were 0.66, 0.77 and 0.75 with the application of HA at rates of 0, 2.5 and 5 kg ha^{-1} respectively. Application of humic substances enhanced uptake of phosphorous in plantsmainly due to the increased availability of phosphate in the soil (Burs *et al.*, 1986; Zalba *et al.*, 2002). A large part of total P in many soils is insoluble (calcium phosphate precipitation) and thus unavailable to the plants. The interference on calcium phosphate precipitation is the major mechanism involved in the effect of humic substances increasing phosphorus recovery (Delgado, 2002; Satisha *et al.*, 2005; Sharif *et al.*, 2002). Root mass and root volume are also generally increased with the application of humic substances being an important factor in nutrient uptake (Burns *et al.*, 1986; Canellas, 2002; Mahmoud *et al.*, 2010).

The second higher concentration of K such as 0.385 mg kg^{-1} was observed in the PDHA followed by 0.335 mg kg^{-1} in CDHA alone has. The foliar has 0. 34 mg kg^{-1}. The highest amount of 2.33mg K kg^{-1} was found in CDHA in combination with MN which is similar to the study conducted by (Mahmoud *et al.*, 2010) where maximum productivity of potato was increasing by K use efficiency under sandy soil conditions. The application of HA along with different K fertilization levels led to increase K concentration in potato tubers. The foliar treatment contained 2.16 mg kg^{-1} and PDHA in combination with MN has 2.15 mg kg^{-1}. The control has 1.89 mg kg^{-1}.

The same trend was seen in the micronutrients concentration in the tubers. The highest Fe content of 128.9 mg kg^{-1} was present in the foliar treatment followed by CDHA+MN having value of 127.5 mg kg-1 which is similar to Selim *et al.* (2009a) where the application of HS as fertigation increased the level of macro and micronutrients that were retained in soil after potato harvesting and was likely due to an improvement of the nutrient supply potentials of those sandy soils. The concentration of iron content in PDHA+MN have 122.5mg kg^{-1}and PDHA alone contained 120.5mg kg^{-1}. The highest content of Zn was 43.8 mg kg^{-1}, found in PDHA+MN followed by foliar application amounting to 42.6 mg/kg.

The PDHA alone has 35.5 mg kg^{-1}. These results are parallel to (Ezzat *et al.*, 2009) where the HS increased the micronutrients concentration in the potato tubers. There was no significant difference in the Cu content and ranged from 6.1 to 7.9 mg kg^{-1}.

Table 3. Chemical composition of tuber.

Treatments	P	K	Fe	Zn	Cu	Mn
	%		(mgkg-1)			
Full NPK	0.315	1.89	116	31	6.35	7.3
75 % NPK+CDHA	0.335	1.96	117	32	7.1	8.1
75 % NPK+PDHA	0.385	2.02	120.5	35.5	7.35	7.8
75 % NPK+CDHA+MN	0.388	2.33	127.5	39	7.9	8.05
75 % NPK+PDHA+MN	0.32	2.15	122.5	43.8	7.7	7.75
75 % NPK+CDHA (foliar)	0.34	2.16	128.9	42.6	6.1	9.05

PDHA=Plant derived humic acid. CDHA=coal derived humic acid. MN=Micronutrients.

Elemental composition of CDHSs, PDHSs (sunflower derived as SFDHSs, and maize derived as MDHSs) presented in Table 4, showed that carbon (C) constitute over 50% followed by hydrogen (H) as ~3% and nitrogen (N) as > 1% in all HSs derived from three sources.

Table 4. Elemental analysis of humic substances

	N	C	H	S
HSs	%			
SFDHSs	1.25	53.48	3.22	0.77
CDHA	1.42	52.31	3.15	0.71

SFDHSs= sunflower derived humic substances, CDHA=coal derived humic acid.

Plant and coal derived humic substances have important effects on plant growth. The humic substances along with fertilizer and micronutrients increased the yield significantly and saved 25% cost of production. It is time to use the plant waste materials and coal by converting into humic substances. The soil fertility level is also increased and production is increased.

Abbreviations. HA=Humic acid, CDHA=Coal derived humic acid, PDHA=Plant derived humic acid, MN=Micronutrients, HSs=Humic substances, MN=Micronutrients.

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