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RESPONSE OF POTATO TO FULVIC ACID AND INORGANIC FERTILIZERS

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ABSTRACT

Increasing crop yield through balanced use of fertilizers in conjunction with organic acids is a need of the time to curtail the use of costly chemical fertilizers as well as to minimize the environmental pollution in Pakistan. Fulvic acid (FA) has potential to improve plant growth and yield. Fulvic acid ($C_{14}H_{12}O_8$) is an acid created in soils due to action of microbes on decaying plant materials under aerobic conditions. Zinc is reported to improve potato yield. The response of potato (*Solanum tuberosum* L.) has not been investigated in planned field experiments to the foliar application of fulvic acid alone as well as in combination with chemical fertilizers and zinc. To bridge this research gap, a field experiment was conducted at the experimental farm (clay loam soil) of Nuclear Institute for Food and Agriculture (NIFA), Peshawar, Pakistan. The experiment was laid out in randomized complete block design with seven treatments and three replicates. Treatments included control, NPK @ 150-100-50 kg ha^{-1}, fulvic acid (150 ppm), $ZnSO_4$ (2.5 kg ha^{-1}) + FA (150 ppm), $ZnSO_4$ (5 kg ha^{-1}) + FA (150 ppm), 1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (2.5 kg ha^{-1}) and 1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (5 kg ha^{-1}). Results indicated that fulvic acid may be a good substitute for chemical fertilizers in future as relatively higher yield was attained in treatments receiving fulvic acid in conjunction with zinc and half of the recommended NPK doses. Further comprehensive long term studies are required to develop recommendations for end-users.

Keywords: fulvic acid; inorganic fertilizers; nutrient availability; potato; tuber yield

INTRODUCTION

Soil fertility management is the key to sustainable crop production. Soils across the globe are losing their fertility and productivity due to their intensive use (Tiemann *et al.,* 2014). Use of nitrogenous fertilizers is particularly contributing towards water pollution through nitrate leaching (Moss, 2008). Nitrous oxide emissions are major contributor towards greenhouse gases whose share is on continuous rise, thereby, contributing to intensify the climate change (Pachauri *et al.,* 2014; Velthof *et al.,* 2014; Nassar, 2015). Organic residues help in improvement of soil fertility and crop yield but their use is limited due to limited availability. Situation demands to identify alternatives to improve crop yield with minimal use of fertilizers so that soil health and crop productivity are not compromised. Extensive use of chemical fertilizers and pesticides, excessive tillage operations, erosion and depletion of soil fertility has resulted in decreased microbial activity in soils across the globe with the consequences of decrease in the concentration of fulvic acid in soils as well as in plants (Nunes *et al.,* 2012; Garcia-Orenes *et al.,* 2013; Marie *et al.,* 2015). In ancient times, soils had enough vegetation and due to microbial action on this decaying vegetation, amounts of FA in soils were enough to sustain healthy soils and plants rich in FA (Tavares and Nahas, 2014). But, now this trend has completely changed as soils are not maintaining adequate microbial activity due to which levels of FA in soils have been drastically reduced. Fulvic acid has positive effects on many important functions in plants including respiration, cell division and elongation, permeability of cell membranes, seed germination and seedling development, chlorophyll synthesis, regulation of plant growth, root stimulation, nutrient uptake, drought tolerance and increase in crop yield (Arancon, 2006; Celik, 2010; Quilty and Cattle, 2011). Fulvic acid increases the concentration of mRNA in plant cells leading to increased concentration of enzymes and proteins (Calvo, 2014). Because of its multiple functions, FA can be used as a primary production technique for maximizing the plant productive capacity. The most abundant natural resources of FA include leonardite/ humate (oxidation products of

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lignite/humus) and black peat that contain 85% and 40% of FA, respectively. Fulvic acid is rich in carbon (44-49%), hydrogen (3.5-5%), oxygen (44-49%) and nitrogen (2-4%) (Saab, 2010).

Pettit (2004) stated that fulvic acid is component of humic structure in rich composting soil. Fulvic acid is created in minute amount by the action of beneficial microbes on decaying plant matter in soils having sufficient oxygen. It is biologically very active and because of its low molecular weight has the potential to readily bond minerals and elements (up to 70 or more) into its molecular structure causing them to dissolve and become mobilized fulvic complexes. This special bonding feature of FA brings nutrient elements in ideal natural form to be readily absorbed by plant roots and interact with living cells and helps plants to retain nutrients in their structure for use in maintaining good health. Pakistan is amongst the developing countries where soil fertility is continuously declining due to intensive cropping for meeting the food demands of rapidly increasing population (Maqsood *et al.,* 2013; Iqbal *et al.,* 2014; Hassan *et al.,* 2016). It is desired to explore alternatives to reduce use of chemical fertilizers for enhancing crop yield. Fulvic acid offers suitable alternative to supplement chemical fertilizers. In Pakistan, most of the research work has been done with humic acid while fulvic acid has not been tested in conjunction with chemical fertilizers to improve yield. Keeping in view the potential of FA to improve nutrient availability and plant growth, an experiment was planned to study the response of potato to FA alone as well as in different combinations of chemical fertilizers (NPK and Zn) with the objective to identify suitable level of FA and chemical fertilizers for achieving higher potato yield.

MATERIALS AND METHODS

A field experiment was conducted at Nuclear Institute for Food and Agriculture (NIFA), Tarnab (longitude 71^{o}50, latitude 34^{o}1), Peshawar during 2014. The experiment was laid out in randomized complete block design with seven treatments and three replicates. Locally adopted potato variety Carora was used in this study as recommended by extension department on account of its low cost and high yield potential. Plant spacing and row spacing was maintained at 12 cm and 70 cm, respectively. The experiment received usual agronomic management from sowing till harvest. The entire quantity of zinc, phosphatic and potash fertilizers was applied as basal dose at sowing on September 18, 2014 except nitrogenous fertilizers that were split into two doses: half at sowing and remaining half at 30 days after sowing (DAS). The fertilizers used were urea, triple super phosphate and sulphate of potash. Zinc was used to verify its reported benefits for promoting potato yield under local conditions. Fulvic acid having molecular weight of 308g/mol was purchased from local fertilizer market, Peshawar. First foliar application of fulvic acid (150 ppm) was made at weekly interval once the leaves have started expansion on 45 DAS and it was repeated twice at weekly interval. One liter solution of fulvic acid was applied uniformly on each plant using manual spray bottle. Foliar application of fulvic acid was made instead of soil application as foliar application needs relatively smaller amounts of acid, ensures quick absorption by plants and minimizes losses of costly acid through leaching in deep soil layers. At flowering stage, data on plant height and chlorophyll content was recorded. Chlorophyll content was measured using SPAD-Chlorophyll meter (SPAD-502, Konica Minolta, Japan) from fully expanded leaves 60 DAS. Harvest of tubers was made 160 DAS to record data on tuber yield. Value cost ratio (VCR) was calculated by dividing monetary value of potato tubers with actual cost of production.

Treatments detail of present study included T1 (Control with basal dose of N), T2 (150-100-50 kg ha^{-1}), T3 (Fulvic Acid 150 ppm), T4 ($ZnSO_4$ 2.5 kg ha^{-1} + FA 150 ppm), T5 ($ZnSO_4$ 5kg ha^{-1}+ FA 150 ppm), T6 (1/2 NPK + FA 150 ppm+$ZnSO_4$ 2.5 kg ha^{-1}), T7 (1/2 NPK+ FA 150 ppm+$ZnSO_4$ 5 kg ha^{-1}). Doses of chemical fertilizers were based on recommendations of local extension department. Zinc was used at full and half dose of 5 and 2.5 kg ha^{-1}. During the crop period, mean daily temperatures ranged from 0-29^{o}C and total amount of rainfall received was 93 mm. The soils were analyzed for physico-chemical properties prior to sowing whose details are presented in Table 1. Nitrogen, phosphorus, potash and zinc content in potato tubers were determined following the standard analytical procedures following Chapman and Pratt (1961) in the laboratory of Soil and Environmental Sciences Division at NIFA, Peshawar. The data collected were analyzed statistically following.Treatment means for each parameter were compared using DMR test at 5% level of probability.

Table 1. Physico-chemical properties of soil

Properties	Value	Reference
pH	8.1	McLean (1982)
Electrical conductivity	2.01 (dS m^{-1})	Rhoades (1982)
Organic matter	0.78%	Nelson and Sommers (1982)
Total N	0.040%	Bremner and Mulvaney (1982)
Phosphorus	8.0 (mg kg^{-1})	Page *et al*. (1982)
Potash	120 (mg kg^{-1})	Grimme (1974)
Zinc	1.71 (mg kg^{-1})	Soltanpour and Schwab (1997)
Texture	Silty clay	Kohler *et al.* (1984)

RESULTS AND DISCUSSION

Influence of fulvic acid on potato growth and yield

Non-significant differences were observed among treatments for plant height in potato. Fulvic acid when used in conjunction with $ZnSO_4$ and NPK increased plant height by up to 6 cm over control. Significant differences (*P*≤ 0.05) were observed among treatments for chlorophyll content in potato leaves (Table 2). Maximum value of chlorophyll content was recorded in treatment 1/2 NPK+ FA (150 ppm) +$ZnSO_4$ (2.5 kg ha^{-1}) and it was 6% more than the control. Potato density differed significantly (*P*≤ 0.05) among treatments and treatment 1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (5 kg ha^{-1}) attained the highest density of 1.17. Application of humic substances improves water and nutrient availability to plants that in turn improves plant and tuber growth in potatoes (Erik *et al.,* 2000; Mahmoud and Hafez, 2010).

Potato tuber yield did not differ significantly under different treatments. Tuber yield ranged from 7.67-10.87 t ha^{-1}. Among various treatments of this study, we found that relatively higher tuber yield of 10.87 t ha^{-1} was attained due to combined application of fulvic acid and $ZnSO_4$ along with ½ dose of NPK. Tuber yield under control receiving no fertilizer was 7.67 t ha^{-1}. Combined application of chemical fertilizers (half of recommended dose) and FA may increase yield by over two tons per hectare. This is critical in terms of saving cost of chemical fertilizers besides reducing negative impacts associated with use of chemicals. The highest VCR of 21.9 was attained when fulvic acid was applied in conjunction with $ZnSO_4$. Data on potato tuber yield and VCR is presented in Table 3.

Influence of fulvic acid on nutrient concentration in potato tubers

Significant (*P*≤ 0.05) differences were observed among treatments for nitrogen (N) concentration. The data on nutrient concentration in potato tubers under various treatments is presented in Table 4. The maximum N concentration (1.77%) was observed in treatment receiving half NPK+ FA (0.05%) + $ZnSO_4$ (5 kg ha^{-1}) while the lowest N concentration was recorded in control treatment. Phosphorus concentration did not differ significantly and ranged from 0.21-0.29%. Differences among potassium (K) content in tubers were significant (*P*≤ 0.05). The highest K content (3.33%) was recorded in treatment receiving $ZnSO_4$ (2.5 kg ha^{-1}) + FA @ 150 ppm while lowest K content (2.5%) was recorded in control treatment. Differences among zinc (Zn) content in tubers were found significant (*P*≤ 0.05). The highest Zn content (20.23 ppm) was recorded in treatment receiving 1/2 NPK+ FA (0.05 %) + $ZnSO_4$ @ 5 kg ha^{-1} and lowest Zn content was recorded in control treatment (13.73 ppm). Randhaw and Broadbent (1965) reported that humic substances produce ligands capable of complexing nutrient elements and the complexed elements remain more available to plant roots as complexation shields them against immobilization in soil. Increased availability of nitrogen can be attributed to reduced losses of N by volatilization (Flaig, 1984) through inhibition of urease activity by humic acid (Vaughan and Ord, 1991). The phosphorus is usually fixed in soils and released slowly over time. This may be the reason behind non-significant differences among treatments in present study. These findings are in agreement with those of David *et al.* (1994) and Heng (1989). The K content is increased due to application of fulvic acid in tubers and can be attributed to impact of humic and fulvic substances on increasing release of K fixed in soils and improving its availability to plants. The increased zinc content may be attributed to its increased solubility and ability of humic substances (humic acid, fulvic acid) to form stable complexes with zinc (Milap Chand *et al.,* 1980).

Table 2. Plant height, chlorophyll content and density under various treatments

Treatments	Plant height (cm)	SPAD Chlorophyll content (%)	Density (g cm^{-3})
Control (basal dose of N)	48	47 b	1.04 b
NPK Full dose (150-100-50 kg ha^{-1})	48	52 a	1.06 b
Fulvic Acid (150 ppm)	48	43 b	1.07 b
$ZnSO_4$ (2.5 kg ha^{-1}) + FA (150 ppm)	53	45 b	1.07 b
$ZnSO_4$ (5 kg ha^{-1}) + FA (150 ppm)	49	45 b	1.07 b
1/2 NPK+ FA (150 ppm)+$ZnSO_4$ (2.5 kg ha^{-1})	54	53 a	1.07 b
1/2 NPK+ FA (150 ppm)+$ZnSO_4$ (5 kg ha^{-1})	50	52 a	1.17 a
LSD (0.05)	NS	5	0.10

Means followed by different letters within a column are significantly different from each other ($P \leq 0.05$).

Table 3. Potato tuber yield and value cost ratio (VCR) under various treatments

Treatments	Potato tuber yield (t ha^{-1})	VCR
Control	7.67	-
NPK Full dose	8.83	0.5
Fulvic Acid (150 ppm)	9.40	17.3
$ZnSO_4$(2.5 kg ha^{-1}) + FA (150 ppm)	9.43	16.0
$ZnSO_4$(5 kg ha^{-1}) + FA (150 ppm)	10.30	21.9
1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (2.5kg ha^{-1})	10.87	2.6
1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (5.0 kg ha^{-1})	10.63	2.4
LSD	NS	-

Table 4. Nutrient concentrations in potato tubers under various treatments

Treatments	N%	P%	K%	Zn (ppm)
Control	0.30 c	0.21	2.50 b	13.73 d
NPK Full dose	1.73 a	0.27	2.66 ab	14.6 d
Fulvic Acid (150 ppm)	1.50 bc	0.28	2.83 ab	14.96 d
ZnSO4 (2.5 kg ha^{-1}) + FA (150 ppm)	1.60 ab	0.27	3.33 a	17.4 c
ZnSO4 (5kg ha^{-1}) + FA (150 ppm)	1.70 ab	0.28	2.67 ab	18.6b c
1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (2.5 kg ha^{-1})	1.73 a	0.29	2.83 ab	18.8 b
1/2 NPK+ FA (150 ppm) + $ZnSO_4$ (5 kg ha^{-1})	1.77 a	0.28	2.83 ab	20.23 a
LSD	0.21	NS	0.68	1.25

Means followed by different letters within a column are significantly different from each other ($P \leq 0.05$).

CONCLUSION

The study was conducted to determine response of potato to combined application of fulvic acid and inorganic fertilizers. We intended to find whether use of fulvic acid in conjunction with chemical fertilizers (half of recommended doses) may affect potato tuber yield. The differences among various treatments were non-significant but we found relatively higher yield under treatment receiving half of recommended NPK with fulvic acid and zinc. Better nitrogen, potassium and zinc concentration in potato tubers due to application of fulvic acid revealed positive impact exerted on nutrient uptake. The results need further confirmation in long term studies to establish positive impact of fulvic acid on nutrient uptake and yield enhancement prior to developing reliable recommendations for end users.

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