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Research Article

Short-Term Impact of Plant and Liquid derived Fulvic Acids on the Physiological Characteristics, Plant Growth and Nutrient Uptake of Maize-Wheat Production

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Abstract: Fulvic acids (FAs) are the major component of soil organic matter, which improves soil structure and fertility. FA has been observed positively on plant growth and ultimately enhances crop production. The pot experiment was conducted on wheat and maize grown in silty clay, sandy loam, and clay loam textural soils, respectively. Three different parent materials; FA Solid (S=Powder Form), Natural Liquid (NL) and Plant-derived Liquid (P) were applied at 0% (Control), 0.25 % (S), 0.50 % (NL) and 0.50 % (P) FA, respectively. The results showed that the stem diameter of maize was 15.68, 26.90, and 26.35 mm under S, P, and NL respectively, however, the spike weight of wheat was 123.24, 98.5, and 132.4 g pot-1 for S, P, and NL in Albic (AL), Irrigated Desert (IR) and Shahjiang (SH) soils. Similarly, maize height increased by 8 % and 9 % significantly as compared to control and the height of wheat increased by 4 % and 1 % in AL and 5 % in IR soil compared to control. Maize grain weight increased over control; however, wheat grain weight significantly decreased. The N and P significantly enhanced in maize and wheat in AL, IR, and SH soils. Our study proved that the application of Solid FA did not improve maize growth characteristics, however, it improved the characteristics of wheat crops except under IR soils. In contrast, liquid FA improved the chemical and physical properties of soils including nutrient uptake of maize and wheat under AL and SH soils.

Keywords: Fulvic acids; Mazie; plant growth characteristics; Nutrient uptake; Wheat

1. INTRODUCTION

Fulvic acid (FA), the major component of soil organic matter, is the subject of study in various areas of agriculture, such as soil chemistry, fertility, plant physiology as well as environmental sciences, because of the multiple roles of this material which can greatly benefit plant growth [1, 2]. The positive properties of FA on plant growth may be attributed to its increase in fertilizer efficiency or enhancement

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of plant biomass [3]. In specific, the root growth increase is generally more obvious than that of root growth [4]. FA has the potential to mitigate the stress of the heavy metal on plant growth [5] and enhance the yield by increasing the nutritional status of soil [6]. FA correlated at efficient concentration sustained the Fe and Zn in solution. In this context, FA has been widely considered as performing a valuable role in Fe acquisition by plants [1,7]. The FA effect is ascribed to the complexing properties of FA, though micronutrients availability significantly increases from soluble hydroxides [8]. Plant metabolism is positively modified with a low mass of FA [4]. Their effects appear to be mainly exerted on cell membrane functions, promoting nutrient uptake [7, 9] and/or plant growth and development, by acting as hormone-like substances [4,10]. While it was also studied that FA increases the chlorophyll content, accelerates plant respiration and hormonal growth responses, increases penetration in plant membrane, etc. Similarly, FAs are also vital for the nutrient uptake of plants. Firstly, they serve as a source of N, P, and K [8] and S [11] through mineralization by soil micro-organisms, and secondly act as the organic matter which influences the supply of nutrients and improves soil properties. Carboxyl and hydroxyl groups of FA significantly increase crop production and plant metabolism and improve respiration activities [12]. Tahir *et al.* observed similar results [13] and they found that plant growth and shoot weight of wheat plants increased when the FA dose was 60 mg kg^{-1}. The same tendencies were reported by Sharif *et al.* in a pot experiment of Maize, he concluded that humic acid significantly increases the shoot weight when applied at 50 mg kg^{-1} [14]. Similarly, Çelik *et al.* reported that when humic acid was extracted from leonardite, the growth parameter, shoot, and dry weight of wheat increased with an increase in the nutrient content of the plant [15]. These results have strongly supported the hypothesis that the beneficial effect of humic and fulvic acid on plant development may be dependent on their capacity to improve nutrient availability for plant uptake under nutrient-deficient conditions. Various scientists reported that humic and fulvic acids increased the concentration of all the reliable and available nutrients uptake [16], while Verlinden *et al.* observed that the nutrient content of Maize, potato, and spinach crops significantly increased by humic substance [17]. The chemical and biological content available in FA or Humic acid increased the cation exchange and nutrient uptake [14].

Food production, distribution, and food security were set as primary national goals of the world; however, increasing population, climate change problems, and fewer production techniques reduce the economic development and agricultural production in China and other countries of the world [18]. To increase grain production and to fulfill, the population requirement, the application of FA began to apply to achieve the nutritional requirements, increase the plant growth characteristics, and nutrient uptake of Wheat-Maize crops.

This study was focused on the influence of FA derived from different materials on physicochemical characteristics, plant growth, and nutrient uptake of Maize-wheat production. We hypothesized that many researchers suggest humic substances (HA/FA) significantly increase the physical, and chemical properties of soils as well as physiological parameters and nutrient uptake of plants. FA of different Varieties such as Solid (S), Liquid (NL), and plant-derived Liquid (P) were used as treatment were obtained from Shandong Quan Linjia fertilizer Co. Ltd (Shandong, China) applied different concentrations on the maize-wheat crop grown on Albic (AL), Irrigated Desert (IR) and Shahjiang black (SH) soils to determine responses of various plant growth parameters (stem diameter, spike weight, plant height, biomass, and grain weight) and uptake of N, P and K.

The purposes of this study are (1) to evaluate the impact of fulvic acids (FA) obtained from different parent materials on the physiological characteristics of Wheat and Maize crops. (2) To evaluate the application of FA on low productive soils to enhance plant growth performance. (3) To evaluate and differentiate the FA performance on best-cultivated soil.

2. MATERIAL AND METHODS

2.1 Experimental soils

Three different soils albic black (AL), irrigated desert (IR), and Shahjiang black (SH) soils are classified as Udic, Aridisols, and Podzoluvisols soils according to the soil taxonomy of China (Soil

Survey Staff, 2014), were collected at the depth of 0-20 cm. The Albic black soil (AL) was sampled from Qiqihar city; district Jianhua (47°21′ N, 123°55′ E) located in the west part of Heilongjiang province, however, irrigated desert soil (IR) was sampled from Roughua village Liangzhou District, Wuwei city (37°55′ N, 102°38′ E) Gansu province and Shahjiang black soil (SH) was taken from demonstration base of Anhui Agriculture university Wanbei comprehensive test station (33°50′ N, 117°16′ E) Anhui province China. The soil samples were shipped to the soil fertility and improvement laboratory institute of environment and sustainable development in agriculture (IEDA). The pot experiment was situated at the institute of environment and sustainable development in agriculture (IDEA, CAAS), experimental farm, which was allocated at (40°09′N, 116°92′E) Shunyi District, Beijing China.

2.2 Basic Properties of Soil

The basic soil properties, such as soil EC, pH, Soil organic matter, total nitrogen, total phosphorus, and total potassium content of the three sites are different. The AL soil had the lowest soil EC and pH (30.1 µs cm^{-1} and 5.26), however, irrigated desert soil (IR) had the lowest soil organic matter (2.2 g kg^{-1}), cation exchange capacity (CEC) (4.6 cmol kg^{-1}) and total nitrogen (0.20 g kg^{-1}) as compared with the AL and SH soils. Similarly, it was observed that SH soil has the highest organic matter, CEC, and total nitrogen content. Other soil properties such as available nitrogen content was highest in AL followed by SH soil, available phosphorus was observed lowest in between the soil. However, total phosphorus (TP) and total potassium (TK) content was not much different between these three soils, although due to the change of parent materials between the soils the silt, sand, and clay content was also changed in which AL soil having a large amount of silt particles and having silty clay texture, however, IR soil was sandy loam in nature and SH soil was sticky when wet because of high clay content and the texture was clayey loam (Table 1).

2.3 Experimental Design

The experiment was conducted at Shunyi, an experimental area of the Institute of Environment and Sustainable Development, Chinese Academy of Agriculture Sciences (CAAS), Beijing, China. FAs were applied at four different concentration 0 (CK), 0.25 % (S), 0.50 % (NL), and 0.50 % (P) treatments with four replications of each treatment. The soil was ground and passed through a 5 mm sieve to remove gravel. The size of the pots was 30 x 50 cm. Plant-derived Solid (S) FA was mixed with 15 kg of soil in the pot. However, the liquid form was applied at first irrigation in a 27 and 29.5 cm diameter and height respectively in the pot.

Maize seeds were sown in summer, similarly, the wheat was sown in the winter season, respectively. A compound fertilizer with a composition of 25 % N, 14 % P_2O_5, and 7 % K_2O, was applied to a total of 15 g pot^{-1} (5 g at sowing, 5 g after transplanting, and 5 g at the maturation stage). Plants were harvested at the mature stage and dried at 65 °C. Each harvested plant part such as leaves, stems, and grains were separated according to the treatments and labeled carefully for the assessment of agronomic parameters of plant height, stem diameter, spike height, total plant biomass, thousand-grain weight, and plant nutrient uptake.

2.4 Elemental Composition of Fulvic acids

The soil-applied fulvic acid (FA) was obtained from Shandong Quan Linjia fertilizer Co. Ltd (Shandong, China). Chemical compositions of the three fulvic acids (FA) are presented in (Table 2).

2.5 Statistical Analysis

The collected data was subjected to One-Way ANOVA by using SPSS software 21.0 (SPSS, Version 21.0, Chicago, IL, USA). The multiple comparisons of means were done by using Tukey's HSD post hoc test. The data are expressed as the mean (n=4) ± SE (standard errors) and multiple comparison tests were performed at a significance level of < 0.05. However, graphs were prepared by using GraphPad Prism 6.

3. RESULTS

3.1 Influence of FA on Maize Diameter and Wheat Spike Weight

Results showed that the application of FA derived

Table 1. Properties of soils used in the experiment (mean ± standard error; n=3).

Soil	EC us/cm	pH	OM g/kg	CEC cmol/kg	AN mg/kg	AP mg/kg	AK mg/kg	TN g/kg	TP g/kg	TK g/kg
AL	30.1	5.26	8.4	21.6	66	0.44	78.0	0.70	0.39	20.4
IR	2063	8.49	2.2	4.6	19	2.4	525.3	0.20	0.39	20.1
SH	132	7.99	11.7	25.2	52	1.19	186.6	0.83	0.39	17.3

*Al (Albic black), IR (Irrigated desert) and SH (Shahjiang black), OM (organic matter), CEC (cation exchange capacity), AN (available nitrogen), AP (available phosphorus), AK (available potassium), TN (total nitrogen), TP (total phosphorus) and TK (total potassium)

Table 2. Elemental compositions of plant-derived solid (S), mineral-derived liquid (NL), and plant-derived liquid (P) fulvic acids.

FA Type	**N**	**C**	**H**	**S**
		%		
S	5.39	25.31	5.75	8.47
NL	10.29	52.476	9.74	14.84
P	10.78	50.61	11.56	16.96

S (Plant-derived solid), NL (Natural-derived liquid), and P (Plant-derived liquid) fulvic acids.

Table 3. Influence of FA on maize diameter and wheat spike weight

FA (%)	Stem Diameter mm (Maize)			Spike Weight g/pot (Wheat)		
	AL	IR	SH	AL	IR	SH
CK	$24.91{\pm}1.43^{a}$	$14.40{\pm}0.88^{ab}$	$25.0{\pm}0.60^{a}$	$99.0{\pm}6.55^{b}$	$76.72{\pm}5.57^{ab}$	$132.4{\pm}8.23^{a}$
0.25 S	$12.92{\pm}1.46^{b}$	$15.68{\pm}1.16^{a}$	$26.16{\pm}0.76^{a}$	$123.24{\pm}6.63^{a}$	$30.3{\pm}5.50^{b}$	$124.2{\pm}8.85^{ab}$
0.50 NL	$24.95{\pm}12.2^{a}$	$12.27{\pm}1.33^{b}$	$26.90{\pm}1.05^{a}$	$97.25{\pm}4.63^{b}$	$87.14{\pm}5.73^{a}$	$126.8{\pm}5.23^{ab}$
0.50 P	$26.35{\pm}0.56^{a}$	$18.16{\pm}2.37^{a}$	$25.77{\pm}1.0^{a}$	$68.51{\pm}8.20^{ab}$	$98.51{\pm}9.21^{ab}$	$76.75{\pm}8.45^{b}$

*Different letters (a, b) show significantly different at (*p<0.05*). Standards are mean ± standard error, (n= 4). Plant-derived Solid (S), Natural-derived Liquid (NL), and Plant-derived liquid (P) on Albic Black (AL), Irrigated Desert (IR) and Shahjiang Black (SH) soils.

from different parent materials significantly increased ($p < 0.05$) stem diameter and spike weight in three soils; AL, IR, and SH (Table 3). In AL, the application of FA significantly increased the stem diameter of maize by 24.9 mm as compared to control (no FA) to 24.95 and 26.3 mm at NL and P, similarly, 14.4 mm in control to 15.6 and 18.16 mm in IR and 25 mm in control, 26.1, 26.9 and 25.7 in SH soils, however, decreased 12.9 and 12.2 mm in AL and IR soils with the application of 0.25 % S, 0.50 % NL and 0.50 % P respectively (Table 3). The results observed an increase of 0.16 % and 5.62 %, 8.33 % and 26.11 % and 4.58 %, 7.6 % and 3.08 % among the treatments, in AL, IR, and SH soil, respectively. However spike weight of wheat was decreased by 48 % in AL, and 15 % in IR soil at 0.25 % S and 0.50 % NL treatments respectively. On an average basis, it increased when compared to control by 3 %, 17 %, and 14 % among the treatments at AL, IR, and SH soils respectively. It is evident from this study that a higher response of FA was observed on SH soil vis-a-vis AL and IR soils which could be ascribed to improvement in soil physical properties. Application of FA increased 123.2 g pot^{-1}, 87.1 g pot^{-1}, and 98.5 g pot^{-1} in AL and IR soil among the treatments. However, decreased 97.2, 68.5 g pot^{-1} in AL, 30.3 g pot^{-1} in IR, and 124.2, 126.8, and 76.5 g pot^{-1} in SH soils among the treatments respectively. Showing an increase of 24 %, 12 %, and 24 % in AL and IR soils respectively. The average increase among the treatments was 24 % in AL, 21 % in IR, and decreased 17 % in SH soils over control.

3.2 Influence of FA on Plant height and Biomass of Maize-Wheat

Plant height and biomass content were significantly and non-significantly increased ($p < 0.05$), with different types, and levels of FA after harvesting of maize and wheat at AL, IR, and SH soils (Figure 1). There was an increase of plant height over the control of 3 % and 5 % in AL, 9 % and 11 % in IR, and 1 %, 11 %, and 1 % in SH soils among the treatments after harvesting of maize, however, decreased 42 % and14 % at 0.25 % S and 0.50 % NL in AL and IR soils respectively (Figure 1 A). An overall, results showed an increase of 8 % and 9 % over control on 0.25 % S, 3 % and 11 % at 0.50 % NL and 5 % and 11 % on 0.50 % P treatments in three soils. Similarly, an increase in the plant height of wheat over control of 4 % and 1 % in AL and 5 % in IR soil and decreased 3 %, 16 % and 12 %, 5 %, 7 %, and 6 % in AL, IR and SH soils respectively among the treatments (Figure 1B). On the other hand, an increase of biomass after maize harvesting over control (no FA) was 38 %, 12 % and 41 %, 23 %, 34 %, and 17 % on AL, IR, and SH soils respectively among the treatments, however, decrease of 74 %, 5 % and 17 % at AL and IR soils among the treatments (Figure 1C). Similarly, biomass content of wheat increased over control by 21 %, 12 %, and 29 % in AL, 8 % and 5 % in IR, and 22 % in SH soil among the treatments, however, decreased by 46 %, 14 %, and 3 % in IR and SH soils on 0.25 % S and 0.50 % P treatments respectively (Figure 1D).

3.3 Influence of FA on Thousand Grain Weight of Maize-Wheat

Grain weight was significantly and non-significantly increased ($p < 0.05$), with different types, and levels of FA after harvesting of maize and wheat at AL, IR, and SH soils (Figure 2). There was an increase in grain weight over the control of 15 % in IR and

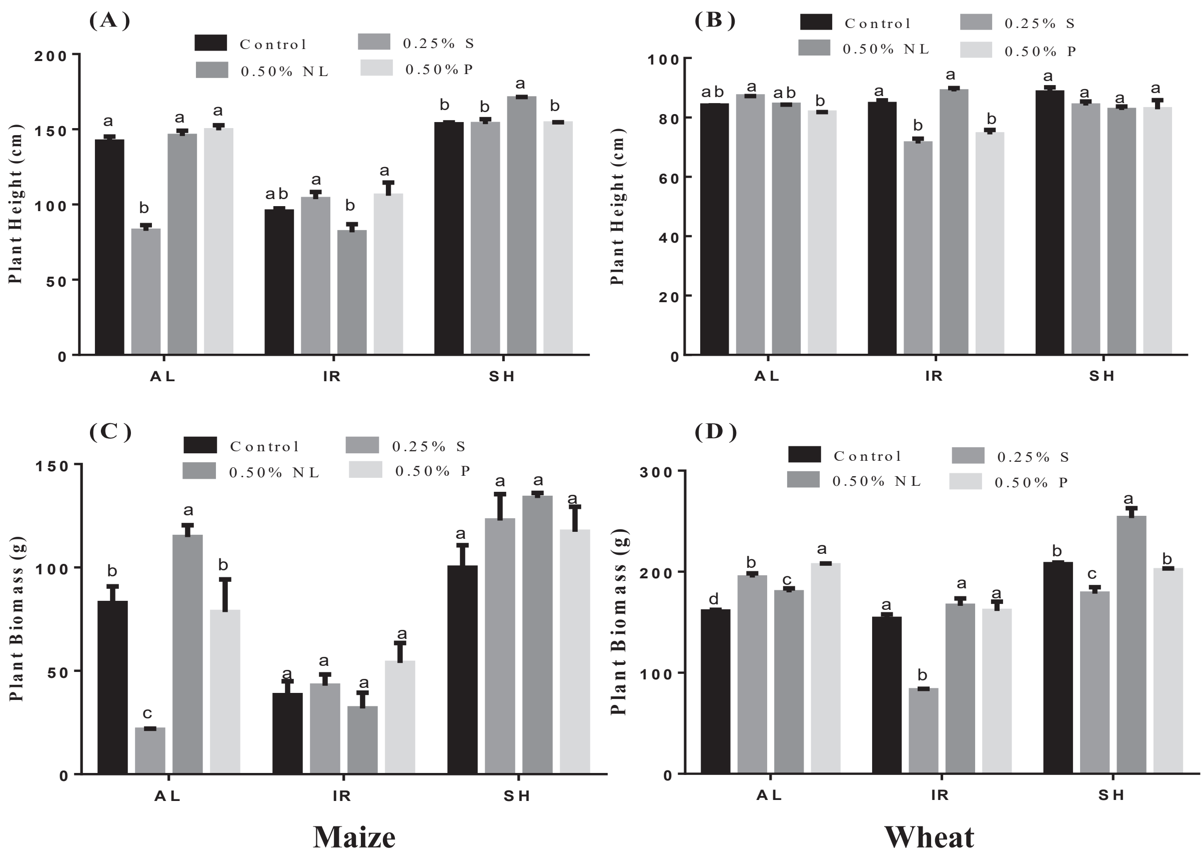

Fig. 1. Influence of 0.25 % S, 0.50 % NL and 0.50 % P FA on Plant height and Biomass on (A) Maize Plant height, (B) Wheat Plant height, (C) Maize Biomass and (D) Wheat Biomass content of dry soil from pot experiment on AL, IR and SH soils. Letters on top show the difference among the treatments, the error bar shows the standard errors of the mean (n=4) with probability (LSD 0.05) at 5 %.

14 %, 34 %, and 2 % in SH soils after harvesting of maize, however, decreased by 46 %, 20 %, and 1 % in AL, 9 % and 8.5 % in IR soils respectively among the treatments (Figure 2). Similarly, the grain weight content of wheat showed a significantly decreased from control by 2 %, 6 %, and 5 % in AL, 16 %, 8 %, and 15 % in IR, and 11 %, 13 %, and 6 % in SH soils among the treatments (Figure 2). Overall, results showed that grain weight content there was an increase in maize grain weight around 15 % in IR soil and 3 % to 34 % in SH soils, however, wheat grain weight significantly decreased and was found lower concentration than maize grain weight.

3.4 Influence of FA on Nutrients Uptake of Maize

Nutrient uptake (N, P, and K) content of maize was significantly and non-significantly increased ($p < 0.05$), with different types, and levels of FA after harvesting of maize at AL, IR, and SH soils (Figure 3). There was an increase of nitrogen over control of 21 %, 34 %, and 52 % in AL, 24 % and 3 % in IR, and 5 % in SH soils among the treatments after harvesting of maize, however, decreased by 14 %, 2 % and 3 % at 0.25 % S and 0.50 % P in IR and SH soils respectively (Figure 3A). Similarly, an increase in the phosphorus uptake over control of 50 % and 16 % in AL, 5 % and 3 % in IR, and 4 %, 1 %, and 5 % in SH soils and decreased 45 %, 14 % in AL, IR soils respectively on 0.50 % P treatment (Figure 3B). On the other hand, potassium uptake increased over control (no FA) was 17 %, 2 %, and 3 % in AL, 6 %, 7 %, and 12 % in IR, and 3%, 4%, and 54% in SH soils among the treatments (Figure 3C). Overall, results showed that Nitrogen uptake was increased by 21 % to 52 % over control in AL, 20 % to 24 % in IR, and 4 % to 5 % in SH soils, however, phosphorus was increased by 16 % to 50 %, 3 % to 5 % and 4 % to 5 % in AL, IR, and SH soil respectively. In the case of potassium, uptake results showed that potassium was highly uptake and increased by 3 % to 17 %, 7 % to 12 %, and 4 % to 54 % in SH soils respectively among the treatments as compared with control (Figure 3).

3.5 Influence of FA on Nutrients Uptake of Wheat

N, P, and K uptake of wheat was significantly and non-significantly increased ($p < 0.05$), with different types, and levels of FA after harvesting of the wheat at AL, IR, and SH soils (Figure 4). There was an increase of 37 % and 9 % in AL, 6 % in IR soils among the treatments as compared with control, however, decrease of 17 %, 12 %, 29 %, 34 %, 47 %, and 32 % among the treatments in AL, IR and SH soils respectively (Figure 4A). Similarly,

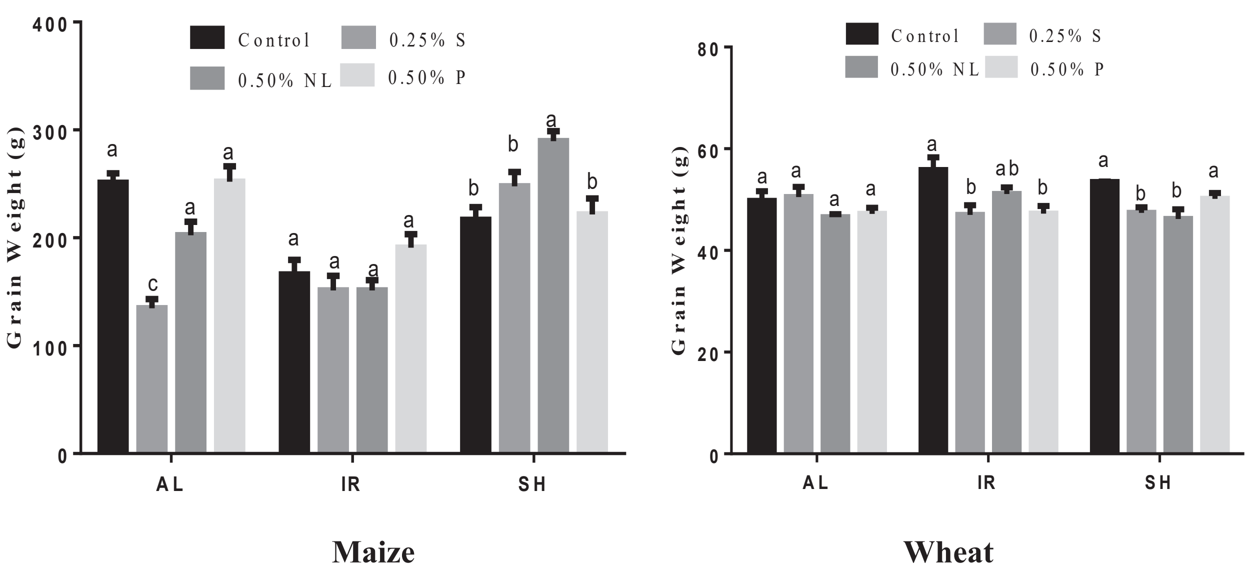

Fig. 2. Influence of 0.25 % S, 0.50 % NL and 0.50 % P FA on Grain weight content of Maize-wheat of dry soil from pot experiment on AL, IR, and SH soils. Letters on top show the difference among the treatments, the error bar shows the standard errors of the mean (n=4) with probability (LSD 0.05) at 5 %.

an increase in the phosphorus uptake over control of 10 % in AL, 8 %, and 2 % in IR and decreased 12 %, and 6 % in AL, 6 % in IR, and 22 %, 7 %, and 12 % in SH soils respectively among the treatments as compared with control (Figure 4B). On the other hand, potassium uptake increase over control (no FA) was 9 % and 8 % in AL, 36 %, 4 %, and 30 % in IR, and 1 % in SH soils among the treatments and decreased by 9 %, 8 % and 1 % among the treatments at AL and SH soils respectively (Figure 4C). Overall, results showed that nitrogen uptake was increased by 22 % over control in AL, and 5 % in IR soil; however, phosphorus was increased by 10 % and 5 % in AL and IR soils respectively. It was also recorded that nitrogen and phosphorus uptake was highly decreased in SH soil. In the case of potassium, uptake results showed that potassium was increased by 9 %, and 23 % in AL and IR soils respectively, similarly, potassium uptake in SH soil was decreased among the treatments as compared with control (Figure 4).

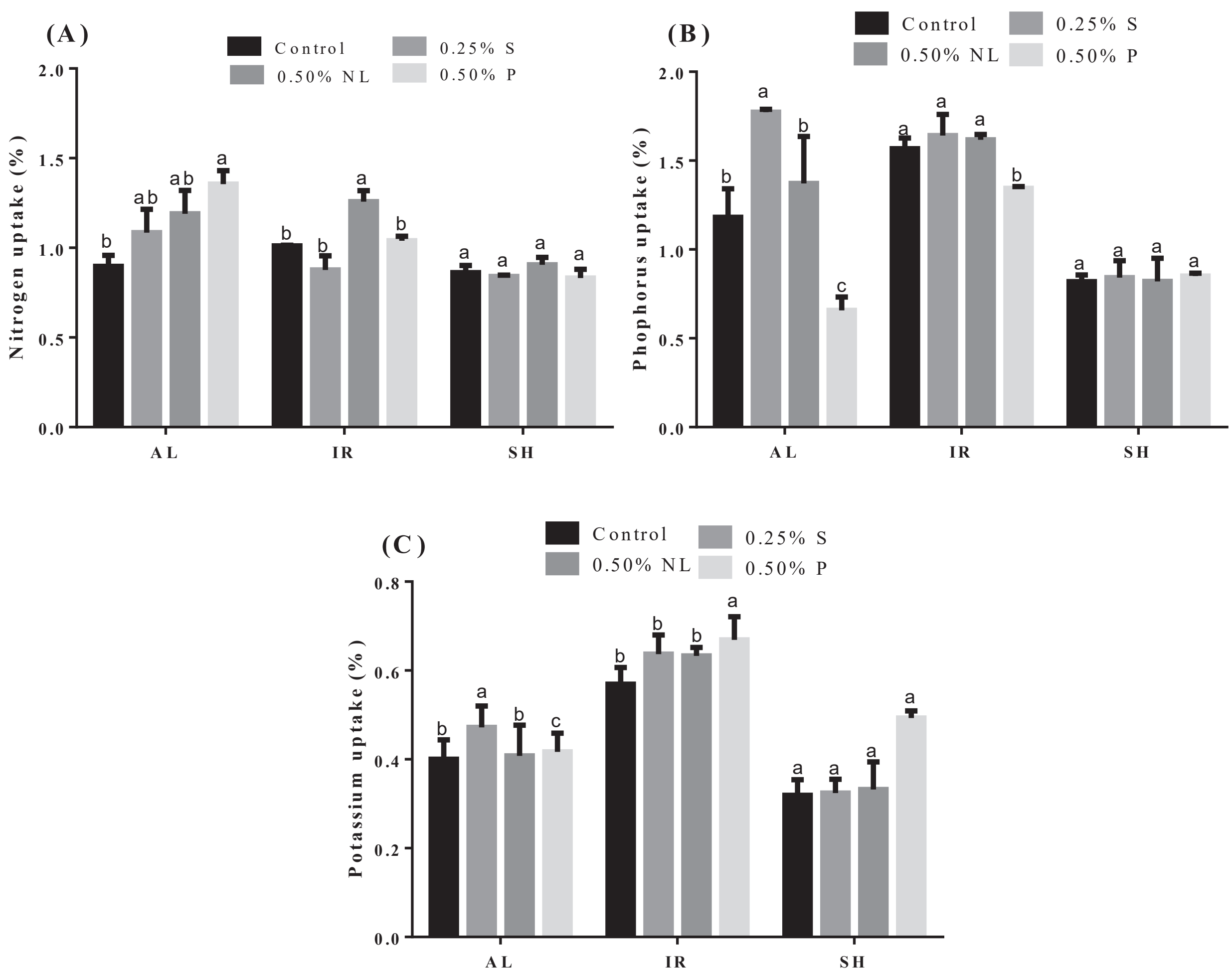

Fig. 3. Influence of 0.25 % S, 0.50 % NL and 0.50 % P FA on Nutrient uptake of Maize of dry soil from pot experiment on AL, IR, and SH soils. Letters on top show the difference among the treatments, the error bar shows the standard errors of the mean (n=4) with probability (LSD 0.05) at 5 %.

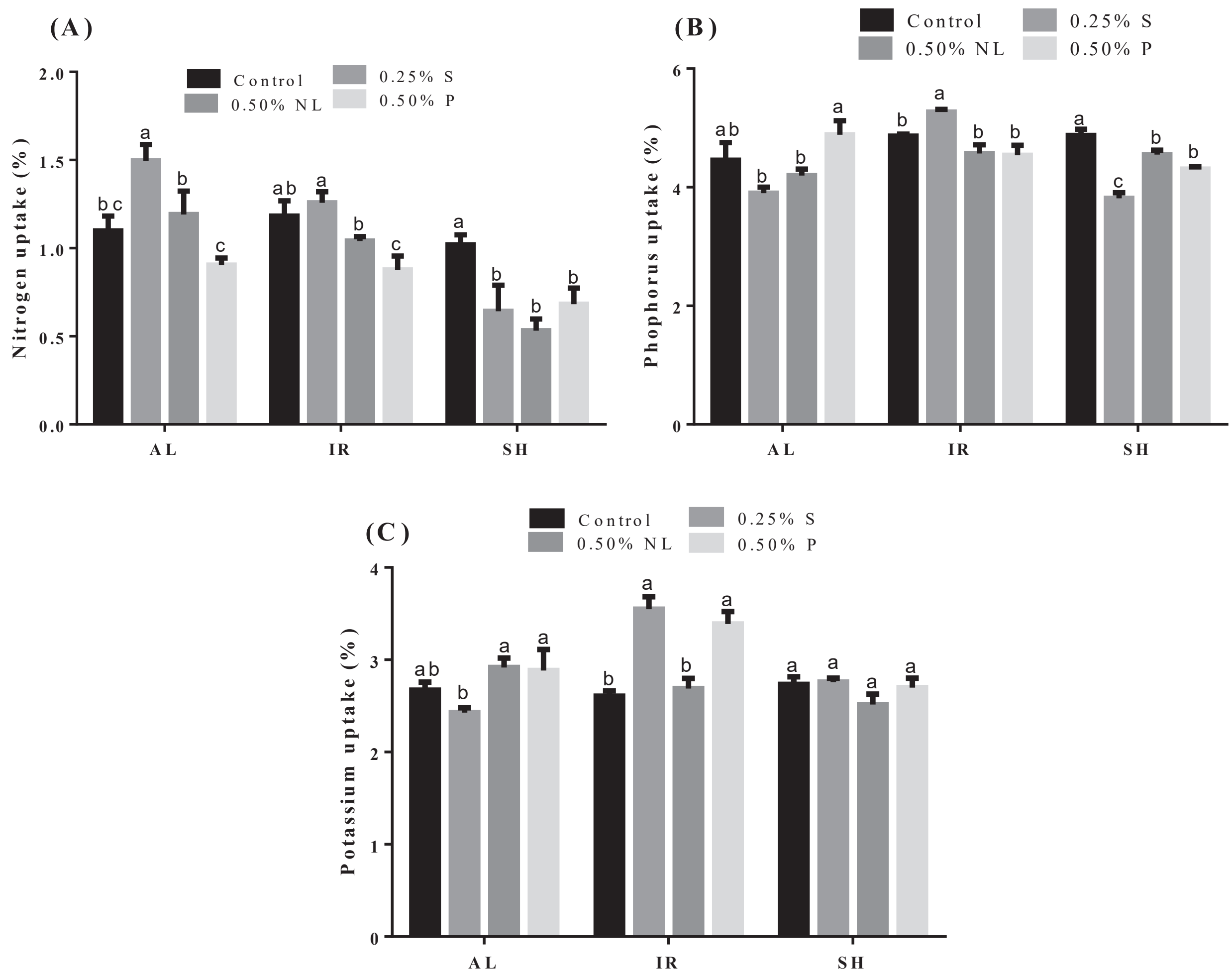

Fig. 4. Influence of 0.25 % S, 0.50 % NL and 0.50 % P FA on Nutrient uptake of Wheat of dry soil from pot experiment on AL, IR, and SH soils. Letters on top show the difference among the treatments, the error bar shows the standard errors of the mean (n=4) with probability (LSD 0.05) at 5 %.

4. DISCUSSION

4.1 Effect of FA on Growth Parameters of Maize-Wheat

Fulvic acid (FA) is a natural product, that improved the physicochemical and biological properties of the soils [19], FA can also ameliorate the soil conditions and bring evenness throughout the plant [2, 20], plant residues are the upright cause of plant nutrients and the vital mechanisms for the constancy of agricultural ecosystems. FA organically improvement of soil increased the yields of some field crops in several studies. Our results indicated that the application of FA significantly increased the stem diameter content of maize on AL and IR soil, and non-significantly increased it in SH soil. It was also observed that application 0.25 % S FA was found lower as compared with the other two FAs. Similarly, the spike weight of wheat was also increased in which the highest spike weight was observed in SH soil as compared with AL and IR soils (Table 3). The increase in stem diameter and spike weight may be due to the positive effect of FA on growth parameters and maybe due to the nutrients supplied by these amendments [21]. FA may augment the plant growth characteristics, nutrient uptake and reduce the perception of harmful components and improve plant metabolism [22]. Our results showed plant growth and biomass content of maize-wheat on AL, IR, and SH soils were increased after FA treatments, however, reduces at 0.25 % S treatment in maize crop. Similarly, it was observed that FA treatments had a better impact on wheat growth parameters as compared with maize (Figure 1). The increase in the growth parameters proves that supplement of HA/FA in soil increased the growth characteristics of plants. The reduction in growth parameters due to 0.25 % S could be because Solid FA was applied in a small amount. There could be another justification which may be because FA in powder form was not dissolved entirely in the soil solution, however the liquid FA mix-up with the soil solution. The plant height of the Petunia hybrid 'Dream Neon Rose' increased with humic acid treatments as indicated by Chamani *et al.* [23]. However, Khaled and Fawy [24] observed that wheat growth was significantly increased by the application of FA and HA weather mixed in soil or with foliar application. Similarly, Sharif *et al.* [14] reported that when a low concentration of FA compared with control in soil significantly increased maize yield, similarly, the higher concentration of more than 300 mg kg^{-1} reduced the yield. FA and HA also increased the yield and yield component of wheat and different grain-producing crops i.e. 1000-grain weight, biological yield, dry matter, grain yield, and harvest index were significantly affected by HA Qin *et al.* and Tuba *et al.* [25, 26]. The present study also indicates that the 1000-grain weight of maize and wheat was increased by the application of FA on AL, IR, and SH soils, the average highest grain weight was recorded in SH soil on the 0.50 % P treatment in Maize crop, however, there was the non-significant difference was observed between the treatment of IR soils as the grain weight was also found lower. Similarly, the 1000-grain weight of wheat was found quite similar in each treatment and a non-significant difference was observed on AL soil (4.2). The results in yield and yield components that were observed in this study was supported by previous findings of Tahir *et al.* [13]. These findings were previously reported by Sharif *et al.* [14] who suggested that the grain yield of maize was recorded higher at low concentrations and observed a significant decline in the yield and non-significantly reduces the grain yield at a higher dose of HA. Similarly, Zhang *et al.* [2] found that it increases the grain yield of legumes such as mung bean (mash bean=moong) (*Vigna radiata* L.), soybean (*Glycine max* L.), and pea (*Pisum sativum* L.). The enhancement of plant growth characteristics of maize and wheat with the addition of FA could be due to the presence of carboxyl and hydroxyl groups and growth-promoting substances such as gibberellins indole acetic acid which may have straight involvement in cell respiration, photosynthesis oxidative enzymatic reactions [16]. The enhancement of root development through FA was outstanding. It was reported by Shahryari *et al.* and Saruhan *et al.* [27, 20] that the root hairs and its development through FA enhanced the plant's physiological characteristics by increasing the nutrient uptake in soil [13].

4.2 Influence of FA on Nutrient uptake of Maize-Wheat

The beneficial effect of humic and fulvic acids on plant development may be dependent on their capacity to improve nutrient availability for plant uptake under nutrient-deficient conditions. Various scientists reported that humic and fulvic acids increased the N, P, and K uptake [16], whereas Verlinden *et al.* [17] have observed that the HA or FA significantly increased the nutrient uptake in maize, wheat, and other vegetable crops. Regarding the above facts, our results indicated that nitrogen uptake in maize was increased by FA treatment and the highest nitrogen uptake was observed in AL soil on 0.50 % P treatment, however, non-significantly decreased on SH soils. Similarly, phosphorus uptake was also significantly increased between treatments on each soil highest observation was recorded at IR soil between the treatments as compared with AL and SH soils. The potassium uptake of maize was increased among the treatments but found non-significant on SH soil (Figure 4). It was also observed that the N, P, and K uptake of wheat was also increased by the application of FA on AL, IR, and SH soils. Nitrogen uptake of wheat was increased between the treatment but decreased on SH soils, the highest N uptake was recorded on 0.25 % S treatment on AL soil as compared with IR and SH soil (figure 4A). However, the uptake of Phosphorus and potassium was increased among the treatments on AL and IR soils and decreased on SH soil. The highest phosphorus and potassium uptake was recorded on 0.25 % S treatment in IR soil (figure 4B & C). FA accelerates the nutrient composition in wheat and maize could be because FA and HS substances are filled with microbiological and other elements [28], and enhance nutrient uptake [29]. Results also correspond with Nikbakht *et al.* [16] studied that the macro and micronutrients content of Gebra leaves was increased significantly when HA was spread at 1g L^{-1}. Similarly, HA increased the nutrient concentration and growth of maize plants even in saline conditions [24]. They have also observed that HA mixed with soil increased N-uptake, whereas foliar application significantly enhanced the other nutrients uptake such as (P, K, Mg, Ca, Zn and Cu). Similarly, HA and straw-derived fulvic acid application also increased the nutrient uptake of watermelon leaves and tomatoes in hydroponic culture and field soils [2, 30, 31].

5. CONCLUSION

FA application increased the growth characteristics of the plant and improves the quality and quantity of fruits crops through the carboxyl and hydroxyl mechanisms which are involved in cell respiration, photosynthesis, water, and nutrient uptake, and enzyme activities. The stimulating effects of FA have been directly correlated with enhanced uptake of macronutrients, such as nitrogen, phosphorus, and sulfur, and micronutrients like Fe, Zn, Cu, and Mn. Due to a decline in the soil's chemical characteristics and reduction in plant growth performance and crop production. To increase crop production and increase the capability of soil characteristics, the plant growth characteristics and plant nutrient uptakes were determined. Our results showed that the application of FA increased the Plant height, biomass, and 1000-grain weight. Besides increasing production, FA also increases the nutrient uptake in plants. It was also observed that application of 0.50 % P FA increased the plant growth characteristics and nutrient uptake of the maize-wheat crop in AL soil, however, application of 0.50 % NL FA increased the plant characteristics of the maize-wheat crop in IR and SH soil. Overall, we found that FA application in liquid forms performs better than the solid FA in IR and SH soils as compared with AL in which 0.50 % P shows better improvement in crop growth in each mentioned soil. It is suggested that to increase the physiological parameters and increase the yield component FA in a Liquid state should be applied in field conditions, and consider the economic level to improve the management strategies

6. CONFLICT OF INTEREST

The authors declare no conflict of interest

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