J. Appl. Res Plant Sci. Vol. 5(2), 281-287, **2024**, https://doi.org/10.38211/joarps.2024.05.281

Research Article

OPEN ACCESS

Available on https://www.joarps.org
Journal of Applied Research in Plant Sciences
(JOARPS)
ISSN: 2708-3004 (Online), 2708-2997 (Print)

Efficiency of Fulvic Acid for Improving Physico-Chemical Properties of Albic Black, Gansu Desert and Shahjiang Black Soils

Mahendar Kumar Sootahar[1,3,*], Mukesh Kumar Soothar[2,4], Ambrin Rajput[3], Muhammad Suleman Memon[3], Muhammad Aslam Panhwar[3], Punam Suthar[5], Abdul Qudoos[3], Khaled Hussain Khokhar[3], Xibai Zeng[1], Hafeez Babar[3]

[1]Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agriculture Sciences, Beijing, 100081, China
[2]Department of Soil Science, Faculty of Crop Production, Sindh Agriculture University, Tando Jam 70060, Pakistan
[3]Soil Fertility Research Institute, Agriculture Research Center, Tando Jam70060, Pakistan
[4]Collage of Natural Resources and Environment, Northwest A&F University, Yangling, 712100, PR China
[5]Department of Statistics Faculty of Social Science, Sindh Agriculture University Tando Jam 70060, Pakistan
*****Correspondences: mahender_935@yahoo.com

Article Received 28-04-2023, Article Revised 27-05-2024, Article Accepted 10-06-2024

Abstract

Fulvic acids are a crucial component of soil that influence various chemical, biological, and physical aspects of soils as well as increase nutrient availability. We examined that application of plant-derived liquid (PDL) fulvic acid on three low obstacle, typical Chinese soil can improve the soil fertility and enhance the plant growth and nutrients uptake. The pot experiments were carried out on three different Albic (AL), Irrigated Desert (IR) and Shahjiang Black (SH) soils, the Plant-derived Liquid (PDL) fulvic acid (FA) was applied at rates of 0.50% as well as control applied at 0% along with three replications. The results showed that PDL FA significantly increases the SOC content in three soils highest SOC was detected at SH, however the SOC fractions were significantly decreased in AL, SH and no-significant difference was recorded at IR. Similarly, the soil pH was significantly increased in AL and decreased at IR and SH, however, the electrical conductivity of IR decreased and increased in AL and SH comparing with initial soil pH and electrical conductivity. The results also examine that available nitrogen, phosphorus of AL, IR and SH soils were increased, however, available potassium content was decreased in IR and increased at AL and SH comparing with initial values. The highest Ca and Mg content was observed in SH and organic degree compound were found 26.7% AL, 49.2% IR and 18.2%, SH soil, conversely the organic-inorganic composite was observed lower. This study suggests that the PDL FA significantly increases the nutrient content of AL, IR and SH soils comparing with initial soil properties.

Keywords: Fulvic acid, Obstacle Factors, Nutrient Uptake, Soil Physical properties, Soil Organic Carbon

Introduction

China's typical soils are Albic black, Shahjiang black, and irrigated desert soils, which are the top three soil types for producing grains nationwide. However, there are many aspects in decline the agriculture on these soils such as albic black (AL) soil having recurrent cycles of wetting and drying which caused the redox process to alternate, bleaching the layer underneath the surface., presence of vermiculite minerals, increase cation exchange capacity, Inorganic-organic compounds and decreases organic matter content in the soil, therefore soil becomes low in production (Akhtar *et al.*, 2014; Zhang *et al.*, 2021). However, scarcer water, land salinization, desertification (Celik *et al.*, 2010; Chai *et al.*, 2014; Daur and Bakhashwain, 2013) and dry climate decrease the amount of substances that are soil organic in irrigated desert soil (Dinka *et al.*, 2013), this type of soil becomes loose in soil aggregates and low in soil fertility (Li *et al.*, 2006; Yildirim *et al.*, 2021). Similarly, because of swelling and shrinkage capacity Shahjiang black soil is very hard during dry and sticky when wet (Lavkulich and Arocena, 2011), due to that aspects agriculture on this type of soil is stops because of poor soil structure (Eyheraguibel *et al.*, 2008; Gumus and Seker, 2015). Alkali-soluble residue is represented by fulvic and humic acids. They offer several advantages to crop production due to their molecular structure. They improve water retention, accelerate seed germination and penetration, break up clay-compacted soils, aid in the transfer of micronutrients from the soil to the plant, and encourage the growth of the microflora population in the soil (Senesi *et al.*, 2001). Humic substances improve soil aggregation, organic matter mineralization, aeration, microbial growth, transport of macro- and micronutrients and the water holding capacity in an indirect manner through fulvic acids and organic manures (Huang *et al.*, 2018; Virgine and Singaram, 2005; Ali *et al.*, 2022). Humic substances significantly impact the respiration rate, cell walls, and photosynthesis in plants (Nardi *et al.*, 2002). Overall, fulvic acids appear to have a direct impact on the physiological characteristics of plants, mainly by improving root development and nutrient absorption. (Eyheraguibel *et al.*, 2008; Ali *et al*., 2022). Given the aforementioned details, fulvic acids were employed in this study to see if they could boost crop yield and improve the availability of vital nutrients. A variety of parent materials were used to create fulvic acids, which were then added to the soil to boost maize crop productivity. Using fulvic acid, the fulvic acid consequence on the nutrient accessibility of three types of soils albic black (AL), irrigated desert (IR), and Shahjiang black (SH) collected from three distinct Chinese province was examined in this study, taking into account the findings of various scientists (M. K. Sootahar *et al.*, 2022). We, hypothesis that application of fulvic acid increased the soil fertility and nutrient uptake of plants, after and before the application in recommended fields. Our research aims to identify the effectiveness of fulvic acid (FA) in different soil types and to examine how FA affects the both physical and chemical properties of soil, the amount of available nutrients, and the uptake of nutrients by the maize crop.

Materials and Methods

Collection of soil samples: Three different soils were plowed at 0-20 cm depth, Albic black soil (AL) were collected from the city of Qiqihar; Jianhua District (47°21' N, 123°55' E) is situated in Heilongjiang's west province, however, Irrigated desert soil (IR) were collected from Wuwei city (37°55' N, 102°38' E) in the province of Gansu, in the Roughua village Liangzhou district and Shahjiang black soil (SH) was collected from the Wanbei Comprehensive Test Station, the demonstration base of Anhui Agriculture University, located in the Chinese province of Anhui (33°50' N, 117°16' E). The soil rehabilitation laboratory at the Institute of Environment and Sustainable Development in Agriculture (IEDA) obtained the soil samples. Located in Beijing, China's Shunyi district at (40°09'N, 116°92'E), the Institute of Environment and Sustainable Development in Agricultures (IDEA, CAAS) experimental Farm was the site of the pot experiment. The soil early properties used in experiment were measured initially before start experiment, soil pH, Soil organic carbon, available Nitrogen, Phosphorus and Potassium content, Total Nitrogen, Total Phosphorus and Total Potassium.

Experimental setup: During this study, a 50 x 60 cm plot was subjected to three treatments of 0.50% plant-derived liquid (PDL) fulvic acid (FA). The design was complete randomized. For every treatment and soil combination, there were three replications. China's Shandong Quan Linjia Fertilizer Co. Ltd. supplied the fulvic acid (FA). Soil that had been air dry was run in the course of a 5-mm sieve. Plant-derived fluid 0.50% (P) fulvic acid (FA) was filled with 15 kg of soil in each pot and applied with water. The pots measured 29.5 cm in height and 27 cm in diameter, respectively. The pots were placed in the ground with their tops parallel to the soil's surface. Every pot contained five different varieties of maize seedlings. Three separate applications of chemical fertilizer (5 grams after seeding, 5 grams upon transplanting, and 5 grams at the maturity stage) totaling 15 g pot^{-1} were made. The fertilizer's composition was 25% N, 14% P_2O_5, and 7% K_2O.Throughout the experiment, equal amounts of water were applied to each pot every 2-4 days. The plants were collected and dried at 65°C once they reached maturity. Plant height, stem diameter, total biomass, and thousand-grain weight were the agronomic characteristics that were measured by labeling and sorting every part of the harvested plant—leaves, stems, and grains—according to the treatments that were used.

Statistical Analyses: The software SPSS (SPSS Version 21.0, Chicago, IL, USA) was used to conduct statistical tests. For the parameters of soil and plants (spike length, plant height, biomass, SOC, N, P, and K,), a one-way analysis of variance (ANOVA) was conceded out. The standard error, or means ± SE, is used to express data. A one-way analysis of variance (ANOVA) was performed on the means (n = 4), and Bonferroni multiple comparison tests were use to compare the results at a significance level of $p < 0.05$. An illustration created using Corel Draw m version X7 shows where the experimental site is located.

Results

Influence PDL FA's on SOM and its Fractions: The labile portions of soil organic carbon and the soil organic carbon of AL, IR, and SH soils both before and after PDL FA application are shown in (Figure. 1). After PDL FA was applied, the soil organic carbon content in AL, IR, and SH soils increased by 42.3%, 19.3%, and 48.8%, respectively, from 8.44%, 2.25%, and 11.7% at the initial application. The light fraction C content was highest in SH 37 g kg followed by 28.7 g/kg in AL, similarly, the heavy fraction C content was highest in AL 12.4 g kg^{-1} followed by 11.9 g kg^{-1} in SH soil. However, IR soil was found to have low soil organic carbon content, and the contents of the light and heavy fraction C were also lower than those of the AL and SH soils.

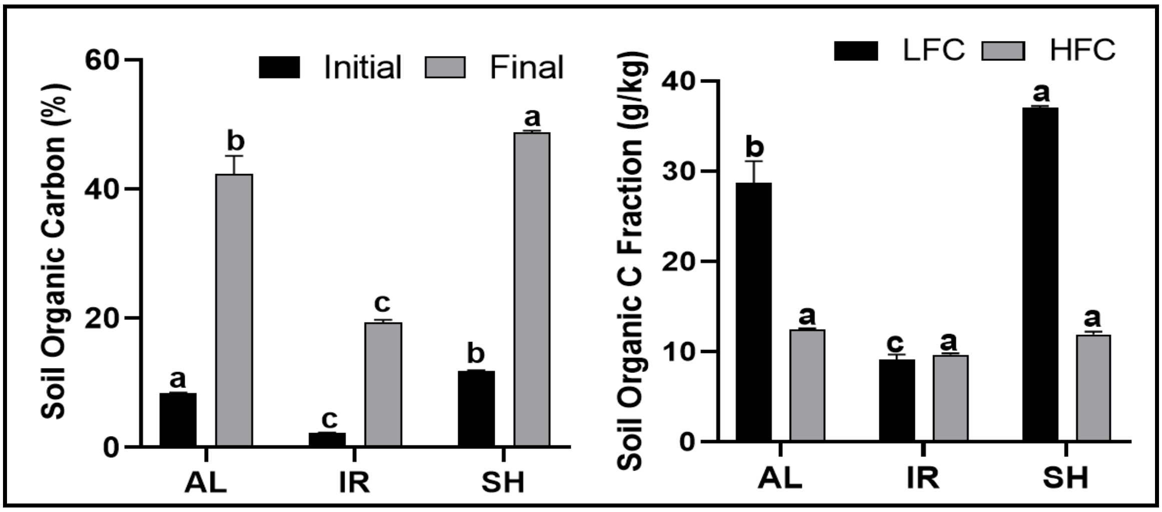

Figure 1. The variation in soil organic carbon on AL, IR, and SH soils before and after applying plant-derived liquid (PDL) FA, as well as in light fraction C (LFC) and heavy fraction C (HFC). Shown are means ± standard errors for n = 4. special letters (a, b, and c) denote significant variations between the starting and end values of the soils based on the least significant difference test at the 5% significance level.

Influence of PDL FA on pH and electrical conductivity: Electrical conductivity and pH of AL, IR, and SH soils before and after PDL FA application are shown in (Figure. 2). After PDL FA was applied, the electrical conductivity in the AL, IR, and SH soils increased by 220, 436.6, and 193.3 µs/cm, respectively, from 30.1, 2063.6, and 123 µS/cm at the beginning. The soil pH was initially 5.25, 8.48 and 7.99 and decreased by 7.79 and 7.33 µs/cm in IR and SH soil and increased by 7.36 µS/cm in A

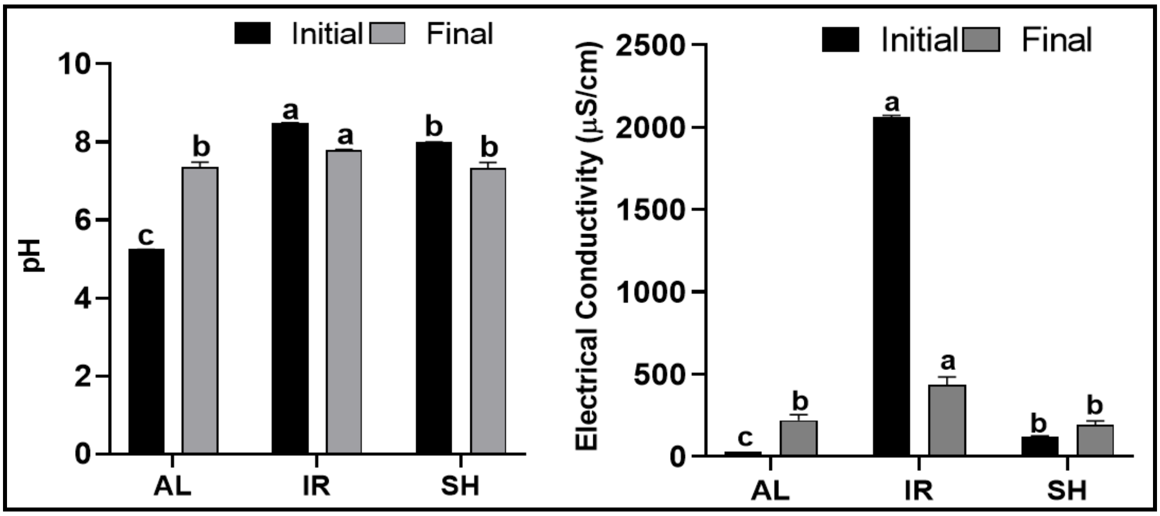

Figure 2. The variations in soil pH and electrical conductivity on AL, IR, and SH soils before and after PDL FA application. Shown are means ± standard errors for n = 4. The various letters (a, b, and c) denote significant variations between the starting and end values of the soils based on the least significant difference test at the 5% significance level.

Influence of PDL FA on available and total nutrients of three soils: PDL FA effect on Available and total NPK of AL, IR, and SH soils are present in (Figure. 3). The results showed that available nitrogen, phosphorus, and potassium content was initially 66, 19 and 52, 10.2, 32.4 and 15.9, and 78, 525 and 186.6 mg kg^{-1} and increased by 101, 44.3 and 96, 133.6, 240.2 and 79.4 and 89 mg kg^{-1} in AL, IR and SH soils respectively and available potassium content was decreased by 202 and 179.3 mg kg^{-1} in IR and SH soils after the application of PDL FA. Similarly, total nitrogen content was initially 0.69, 0.19 and 0.82 g kg^{-1} and decrease by 0.14, 0.12 and 0.21 g kg^{-1} in AL, IR, and SH soil correspondingly. The total phosphorus content was initially 0.38, 0.39 and 0.395 g kg^{-1} and increased by 0.47 and 0.42 in IR and SH soil and decreased by 0.26 g kg^{-1} in AL soil. However, after PDL FA was applied, the total potassium content in the AL, IR, and SH soils dropped by 18.5, 16.3, and 12.3 g kg^{-1}, respectively, from its initial values of 20.4, 20.1, and 13.8 g kg1

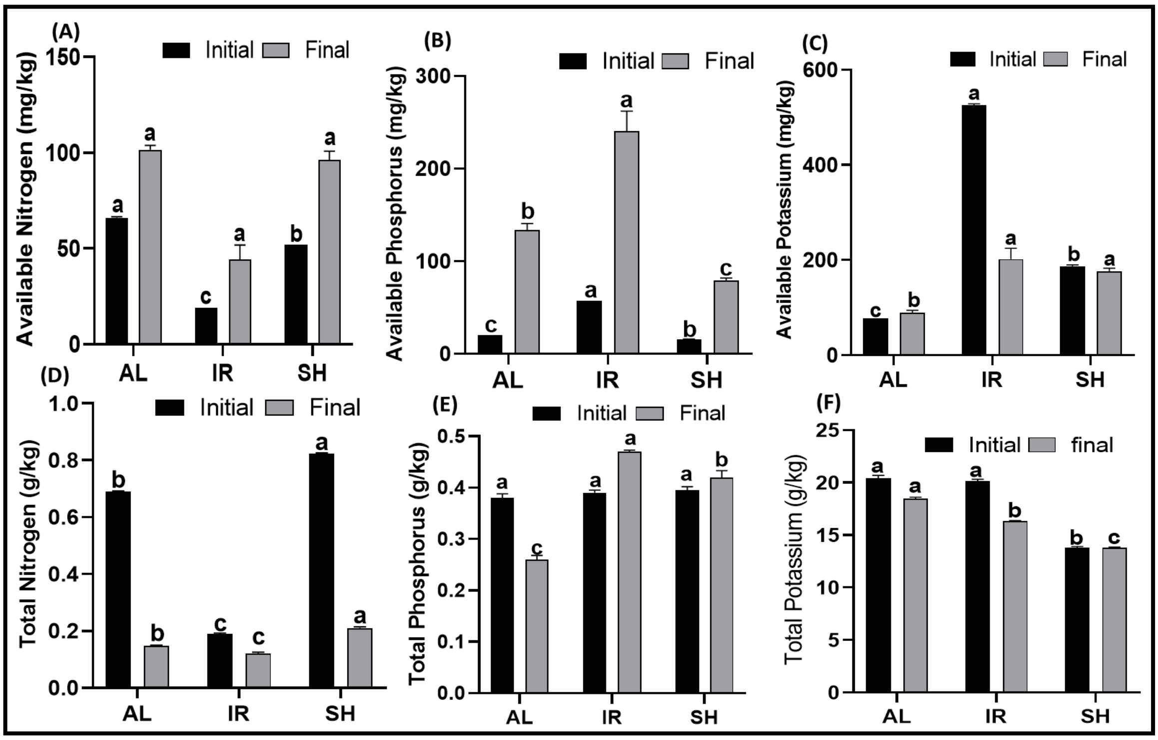

Figure 3. The variation in total and available nutrients on AL, IR, and SH soils before and after PDL FA was applied. Shown are means ± standard errors for n = 4. The various letters (a, b, and c) denote significant variations between the starting and end values of the soils based on the least significant difference test at the 5% significance level

Organic-inorganic composites, degree compounds containing organic and inorganic substances, and exchangeable calcium and magnesium: The organic-inorganic compound and composite contents, exchangeable Ca, and Mg of AL, IR and SH soils were determined (Table 1). Each soil had different chemical properties; the Ca content was highest in SH (578 meq/L) followed by IR (498 meq/L). The Mg content was also highest in SH (50.6 meq/L); however, Mg content was similar in the IR and SH soils. The content of organic-inorganic compounds after the application of PDL FA was highest in IR (49.2%); however, the content did not differ much between AL and SH soils. In contrast to organic-inorganic compounds, the amount of organic-inorganic complexes was quite low in all three soils, with the highest content, 10.9 g kg^{-1}, observed in AL soil.

Table 1. Influence of Plant-derived Liquid (PDL) FA on Organic-inorganic composite, degree compound of organic-inorganic, exchangeable calcium, and magnesium.

Soils	Ca meq/L	Mg meq/L	Organic–Inorganic Degree Compound (%)	Organic–Inorganic Composite (g/kg)
Albic Black	189.3±5.1^{c}	22.0±0.91^{b}	26.7±1.40 ^{b}	10.90±0.10 ^{a}
Irrigated Desert	498.3±13.6 ^{b}	31.5±1.25 ^{a}	49.2±1.68 ^{a}	9.22±0.27 ^{b}
Shahjiang black	578.0±36.7 ^{a}	50.6±1.58^{b}	18.4±0.42 ^{c}	9.02±0.23 ^{b}

Data are mean of (n = 4). Means followed by different letters (a, b& C) are significantly different from each other at (p< 0.05). Values are meant ± standard error, (n= 3), on Albic, Irrigated Desert and Shahjiang black soils, (Ca) Calcium and (Mg) Magnesium content.

Discussion

Fulvic acids (FA) have been used more frequently in recent years. For soil productivity and plant production, it's also critical to improve soil conditions and create nutrient equilibrium. In numerous investigations, the yield of some field crops was raised by FA and organic soil improvement (Saruhan *et al.*, 2011; M. K. Sootahar *et al*., 2022) According to our findings, the physical and chemical characteristics of AL, IR, and SH soils were reportedly enhanced by the application of PDL FA when compared to their initial state. When comparing the initial SOC with the soils after PDL FA was applied, it was also noted that the fraction of soil organic carbon increased. In contrast to AL and IR soils, SH soils had higher soil organic carbon level and its fractions (Figures 1 A and B). PDL FA is a combination of organic particle that improve soil organic matter (SOM) in most clay natural soils, which may account for the increased amounts of soil organic carbon and its fraction in soils following application. Additionally, the soil's mineralization of organic matter was enhanced by these organic particles. Another reason the higher soil organic carbon in SH soil could be because high shrinkage capacity of SH soil (Huang *et al.*, 2018). Similarly, pH of IR and SH soils decreased and increased at AL, however, electrical conductivity (EC) of AL and SH soils increased comparing with initial pH and EC (Figure. 2 A and B). IR and SH soils are alkaline soils, IR soils containing high percentage of Ca (Li *et al.*, 2006; Zhang *et al.*, 2021), while SH soils are heavy compacted soils and sticky in nature (Lavkulich and Arocena, 2011). The quinone groups presence, like carboxyl, hydroxyl phenolic groups, may be the cause of the pH of soil decrease and EC increase. Quinone groups can also break down the parent material of the soil (Sharif *et al.*, 2002). FA neutralized the pH of both (acidic/alkaline) soil conditions (Malan, 2015). These findings are in accord with those of Celik *et al*. (2010) stated that HA combined with NaCl decreases the pH of calcareous soil conditions. Sootahar et al. (2019) suggesting the application of PDLF and MDLF significantly increased the pH and EC of AL soil.

FA increases N, P, and K's availability and facilitates them easier absorption. FA further permits the breakdown of nutrients into their most basic ionic forms, which are chelated by the FA electrolyte, through mutual interactions (Millán *et al.*, 2012; Nardi *et al.*, 2002). Our results indicated that PDL FA increased the AN, AP content of AL, IR and SH soils comparing with initial properties. It was also observed that the highest AN and AP were observed at AL and IR respectively, however, AK increased at AL soil comparing with initial soil properties and IR and SH soils (Figure. 3 A, B and C). Similarly, TN and TK content of AL, IR and SH soils were decreased after the application of PDL FA comparing with initial properties. However, TP content was increased at IR and SH soils comparing with AL soil (Figure. 3 D, E and F). Increased AN, AP content in AL, IR and SH soils could be because FA strongly affected the release of macronutrients in soils (Sharif *et al.*, 2002). Given that potassium is correlated with soil texture and parent material and nitrogen in AL soil is closely connected to humus content, the rise in AN and AK in AL soil may be the explanation (Kravchenko *et al.*, 2011). These findings are in accordance with those of (Tahir *et al.*, 2011), suggesting that the application of FA increases the available N content of soil. Akhtar et al. (2014) stated that appliance of 2.5 kg^{-1} FA and 5 ton ha^{-1} of mung bean residue increased the N content in soil and in wheat grown in the soil, and that at a rate of 20 kg ha^{-1} application of HA enhanced the soil N content (Virgine and Singaram, 2005). Similarly, increase of AP and TP in IR soils could be because IR soil has great viscosity and are rich in phosphorus content (Chai *et al.*, 2014). These outcome are in harmony with the results of (Du *et al.*, 2013) found that the combined use of FA and P fertilizer mono-calcium phosphate (MCP) increased the P concentration of water-extractable P, acid-extractable P and Olsen P in the soil. (Saruhan *et al.*, 2011) also reported that FA decreased the P concentration in soil, which may also reduce the P uptake in maize. The authors suggested that this was due to the reaction of P with phenolic functional groups on the HA ion, leading to the formation of complexes with P that are unavailable to plants (Saruhan *et al.*, 2011; M. K. Sootahar *et al.*, 2022).

The significant impact of these humic substances (FA and HA) on soil properties and the texture was reported earlier (Sootahar*et al.*,2017; Lavkulich and Arocena, 2011; Sootahar *et al.*, 2019). However, there has been limited research on FA derived from the plant material and its effect on soil organic carbon and its fractions, organic minerals, and soil-available nutrients. Kadam et al. (Kadam *et al.*, 2010) reported that humic chemicals have chelating properties, thereby preventing the development of precipitates and the soil's micronutrients' leaching ,oxidation, and fixing. However, Sharif et al. (2002) stated that application of lignite coal HA increases the nutrient uptake and that this is mostly related to HA's ability to enhance the soils' biochemical environment. Similarly, Gumus et al. (2015) also reported that FA significantly increased the essential nutrients (N, P, K, S) cycles, soil stability as well as the ecological and environmental facets of soil fertility sustainability.

Primary macronutrients (N, P, and K) are not the only factors that affect soil fertility; secondary macronutrients are also very important for controlling the interactions between plants and soil. When present in appropriate amounts in the soil, secondary macronutrients enhance plant growth characteristics and fertility, which is crucial for plant growth. (Sootahar*et al.*, 2017). Our results showed that Ca and Mg content was observed higher at SH soil comparing with AL and SH soil and soil initial properties, similarly, Organic degree compound was higher at IR soil and organic composites were observed higher at AL soil comparing with IR and SH soils (Table 1). The increase of Ca and Mg content in SH soil could be because of the availability of high clay content and shrinkage of the capacity of SH soils (Wei *et al.*, 2018). These results sustain the results of (Mayhew, 2004) who suggested that the contents of HA, organic matter and cations were correlated and that HA provides extensive benefits to soil and plants. Sharif et al. (2002) reported that FA forms complexes with K, sodium, Ca, Mg and various other elements and that application of FA can overcome the deficiency of particular elements in the soil.

Our experiment results demonstrate that PDL FA increases the soil physical properties, available nutrients, soil organic carbon fractions and organic mineral content of AL, IR and SH soils comparing with initial soil properties. It was also observed that PDL FA had a stronger effect on properties of SH soil comparing with initial properties and AL, IR soils. The presence of functional groups in the PDL FA, among which are carboxyl, phenolic hydroxyls, and alcoholic hydroxyls, which cause protons to dissociate and lower pH values, may account for the increases in the properties of the AL, IR, and SH soils. In clayey soils, FA loosens up compacted soils, facilitating better water penetration and root growth; in sandy soils, on the other hand, FA improves organic matter, promoting improved root growth and water retention while preserving essential plant nutrients (Khaled and Fawy, 2011).

Conclusion

Fulvic acid improves the physical and chemical properties of and also play significant role to enhance the crop growth. PDL FA had a great impact on the Al, IR and SH soils physical and chemical properties. Over findings concludes that FA addition increased the soil organic matter content however, reduces the organic fraction. Similarly, enhanced the pH of AL soil reduced decreases the IR and SH soils and improved the electrical conductivity after the application. However, it was observed that available N and P was increased after the application in all three soils, meanwhile total NPK content were decreased, observing not much changing. Overall, we observed that PDL FA directly had major influences on the physical and chemical properties of SH soil as comparing with initial properties and AL and IR soils. We suggested that field trail on SH soil should be conducted to assess the overall physiochemical properties and improvement of crop growth.

Funding

This research was funded by Natural Science Foundation of China (41671308) and the Science Innovation Project of the Chinese Academy of Agricultural Sciences (CAAS-ASTIP-2016-IEDA).

***Conflicts of interest*:** The Authors declare that there is no conflict of interest.

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