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# Improvement of Soil Fertility and Rice Productivity with Use of Coal Derived Humic Acid and Mineral Fertilization under Inceptisol of Varanasi, India

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**Abstract**

Use of organic and inorganic fertilizers in balanced and integrated manner may enhance the accumulation of soil organic matter and improves soil physical properties. A two year replicated pot experiment was conducted to assess the influence of coal derived potassium humate (PH) and mineral fertilizers. The experiment followed a completely randomized 2×3×2×3 factorial design comprising two fertility levels (75 and 100% NPK), three doses of PH (0; 5.0; and 10.0 mg $kg^{-1}$), two doses of zinc sulphate (0; and 12.5 mg $kg^{-1}$). Results showed significant enhancement in rice grain yield as well as availability of nutrients with sole and combined application of 10 mg $kg^{-1}$ PH with 100% NPK and 12.5 mg $kg^{-1}$ zinc sulphate as compared to 75 and 100% of NPK alone. Meanwhile, use of $PH_{10}$ showed ~35% higher grain yield compared without $PH_0$ application, it was ~19% higher as compared to $PH_5$. Significant interaction effect of different levels of PH with NPK and zinc was observed in grain yield. Application of 100% NPK with 10 mg $kg^{-1}$ PH significantly enhances nutrient availability as compared to control treatment after rice harvest. These results suggested that the used of PH and mineral fertilization in integrated manner enhance the crop productivity as well as soil fertility of rice system in the alluvial soil under Indo-Gangetic Plain of India.

***Keywords:*** Potassium humate; mineral fertilization; rice productivity; soil sustainability

## 1. Introduction

Nowadays, rising cost of chemical and mineral fertilizers and enhance the illness effects arising in soil-water-plant system from their imbalanced application has made the use of organic manures imperative for cutting down the quantity of chemical fertilizers without sacrificing the crop and soil sustainability. Due to the imbalanced fertilization in Indian agriculture from few decades it is noticed that majority of the Indian soils have become deficient in nitrogen (N), low to medium in phosphorous (P) and over time, potassium (K) deficiency has also become widespread because of continuous removal of nutrients from the soil by the crops over a period. The chronic uses of industrial NPK fertilization have damaged the properties of soil (Lim et al., 2015), and caused many serious agro-ecological problems (Singh and Verma, 2007). The reinstallation of soil sustainability is mostly dependent on adequate presence of soil organic matter (SOM) in the soil-plant system. However, in view of the limited availability of organic resources and their fast decomposition under tropical conditions, there is a need to adopt new strategies involving unconventional sources of such organic inputs which are resistant to decomposition (Lim et al., 2015).

One of the novel organic material is PH such material which has been reported (Turgay et al., 2011; Kumar et al., 2013) to have potential to improve soil and environmental sustainability (Ibrahim and Ramadan, 2015). It is a concentrated form of humus in the naturally occurring ignites which is the brown coal that accompanies coal deposits. This is an eco-friendly novel material which could sustain soil and crop productivity. The humic acid (HA) consists of conglomerate chemically reactive functional groups (carboxyls, phenolic, and alcoholic hydroxyls) as well as pH dependent properties (Alvarez-Puebla et al., 2005). It is a low cost natural supplement for improving cycling and availability of nutrients, soil health and crop growth, the improving in soil fertility, quality and crop productivity in response tolignite coal-derived humic acid (Arjumend et al., 2015).

This novel organic materials applied to soil can support buildup of SOM and nutrient status of the soil and these soils have usually a more active microbial population (Vallini et al., 1993). This in term improves soil sustainability as a result of increased SOM content and concurrent decreases in soil borne diseases. Humic substances also influence indirectly the rhizospheric microorganisms through their cation exchange capacity (CEC). Therefore, essential cations are either made available such as iron (Fe) or toxic concentrations of copper (Cu) are chelated and allowing microbial growth (Charest et al. 2004). Nowadays, humic substances were combined used with helpful microorganisms as plant growth promoter (PGP) or biological control agents to enhance crop sustainability (Naidu et al., 2013; Olivares et al., 2015).

India has the largest area under rice cultivation (~43.8 M ha) and occupies second position in production (~104.8 Mt) next to China among rice growing countries of the world (Anonymous, 2015). The relatively poor productivity of rice in India is also linked with low organic carbon content of rice growing soils. Still very little research work has been carried out in the direction to use of humic acid by cereals crops.

## 2. Materials and Methods

A two year replicated pot experiment was conducted in the net house of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India, located between 25.14º and 25.23ºN latitude and 82.56º and 83.03ºE. The soil was an alluvial representing an Inceptisol (Typic Ustochrept). For conducting the pot experiment, the bulk surface soil (~15 cm) was collected from the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The experimental soil had sandy loam texture, 1.43 Mg $m^{-3}$ bulk density, 2.62 Mg $m^{-3}$ particle density, 7.9 pH, 0.211 dS $m^{-1}$ EC, 4.3 g $kg^{-1}$ organic carbon, 185 kg $ha^{-1}$ available nitrogen, 17 kg $ha^{-1}$ available phosphorus, 199 kg $ha^{-1}$ available potassium, and 10.24 mg $kg^{-1}$ available sulphur. The PH used for experimentation, obtained from Gangeya Agro India Ltd. Lucknow, India. Product was manufactured by Pranav Bio. Tech, Mumbai, India. It contained ~70% humic acid, 49.5% total carbon and ~10% potassium with ~95% solubility. The collected bulk soil sample was air-dried under shade and crushed with a wooden roller and passed through sieve having openings of 2 mm diameter and ~ 8 kg of soil filled in the each polythene lined pot. Soil in each pot was puddled manually with the help of wooden rod and five seedlings of rice (variety Malviya-36) transplanted. After establishment, four plants were maintained. The experiment followed a completely randomized 2×3×2×3 factorial design comprising two fertility levels (75 and 100% NPK), three doses of PH (0; 5.0; and 10.0 mg $kg^{-1}$), two doses of zinc sulphate (0; and 12.5 mg $kg^{-1}$), with three replicate, hence total 36 pots were arranged. Treatments of recommended dose of fertilizers (60 mg $kg^{-1}$ N, 30 mg $kg^{-1}$ P and 30 mg $kg^{-1}$ K) Zn and PH in mg $kg^{-1}$ soil using stock solutions of urea, $KH_2PO_4$, KCl, zinc sulphate and PH, respectively was applied to all the pots. The pots were irrigated and ~2 cm of standing water was maintained by daily addition of water. The initial physico-chemical properties of experimental soil are given in Table 1.

The samples were collected after harvesting of rice crop and analyzed for pH, EC, as per the procedure described by Jackson (1973). Cation exchange capacity (CEC) was determined by leaching the soil with 1*N* $NH_4OAc$ and subsequently displacing the adsorbed $NH^{4+}$ following the methods of Schollenberger and Simon (1945) and bulk density by (Richard 1954). The soil organic carbon was determined by wet digestion method of Walkley and Black (1934) and the available nitrogen was estimated by Subbaiah and Asija (1956). The available phosphorus in the soil was extracted by employing Olsen extractant (0.5 M $NaHCO_3$, pH 8.5) as described by Olsen et al. (1954) and the exchangeable potassium was extracted by using neutral normal ammonium acetate (pH 8.5) and the content was determined by aspirating the extract into flame photometer (Jackson, 1973). The available S was extracted with 0.15% calcium chloride solution and estimated as described by Chesnin and Yien (1951) and the content of DTPA extractable zinc were estimated using 1:2 soil to extractant ratio (Lindsay and Norvell 1978) by atomic absorption spectrophotometer manufactured by Unicam Atomic Absorption Ltd., York street Cambridge.

The statistical analysis of the data was done by the analysis

Table 1: Effects of potassium humate and chemical fertilizers on grain yield

| Treatments | Grain yield (g $pot^{-1}$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | | Mean | 2010 | | Mean | 2009 | | Mean | 2010 | | Mean |
| | $NPK_{75\%}$ | $NPK_{100\%}$ | | $NPK_{75\%}$ | $NPK_{100\%}$ | | $Zn_0$ | $Zn_{12.5}$ | | $Zn_0$ | $Zn_{12.5}$ | |
| $PH_0$ | 30.29 | 36.61 | 33.45 | 30.51 | 36.76 | 33.63 | 32.44 | 34.45 | 33.45 | 32.65 | 34.62 | 33.63 |
| $PH_5$ | 34.59 | 40.23 | 37.41 | 35.36 | 42.40 | 38.88 | 36.38 | 38.44 | 37.41 | 37.64 | 40.12 | 38.88 |
| $PH_{10}$ | 42.94 | 45.68 | 44.31 | 45.06 | 47.23 | 46.14 | 41.76 | 46.85 | 44.31 | 43.07 | 49.22 | 46.14 |
| Mean | 35.94 | 40.84 | | 36.97 | 42.13 | | 36.86 | 39.91 | | 37.78 | 41.32 | |
| NPK× PH | SEm± | LSD (*p*=0.05) | | SEm± | LSD (*p*=0.05) | PH× Zn | SEm± | LSD (*p*=0.05) | | SEm± | LSD (*p*=0.05) | |
| | 0.63 | 1.84 | | 0.65 | 1.90 | | 0.63 | 1.84 | | 0.65 | 1.90 | |

of variance (ANOVA). The means were tested for significance at $p \leq 0.05$.

## 3. Results and Discussion

Data showed that PH treatments, significantly greatest mean grain yield was obtained from the treatment of $PH_{10}$ (44.31 g pot$^{-1}$) fallowed by $PH_5$ (37.41 g pot$^{-1}$), it was significantly superior compared to $PH_0$ (33.45 g pot$^{-1}$). Similar to from the first year, the greatest value was obtained by the treatment of $PH_{10}$ fallowed by $PH_5$ and the effects of combined treatments of PH with chemical fertilizers (PH×NPK) and PH with zinc sulphate (PH×Zn) on grain yield were more apparent and gave greater values than treatment $NPK_{75\%}$ and $NPK_{100\%}$ alone (Table 1). The significantly highest grain yield in addition of PH in present study reveal that humic acid enhanced the availability of the plant nutrients and improved yield components and yield of rice crop. Application of PH along with micronutrients increased ~30% yield of crops (Ibrahim and Ramadan, 2015; Suh et al. 2014; Canellas et al., 2015).

Results showed that the application of 10 mg kg$^{-1}$ PH significantly reduced pH of the soil as compared to 5 mg kg$^{-1}$ PH. It may be due to initially alkalinie in soil reaction being reduced due to submergence during rice cultivation (Shahid et al., 2012; Guo et al. 2010). As a consequence of the reduction of the pH of soil we found that EC of the soil was significantly higher in PH treated pots as well as with $NPK_{100\%}$ than $NPK_{75\%}$ in both the years (Table 2). This was may be due to release acid forming compounds from decomposing organic materials that reacted with the sparingly soluble salts which already present in the soil and either at least increased their solubility or converted them into soluble salts. The decrease in pH of the soil might have also enhanced the discharge of inorganic salts thereby increasing EC of the soil (Bai et al., 2010; Kutuk et al., 2000).

There was a steady increase in CEC with increased levels of potassium humate. The highest CEC was observed with $PH_{10}$ followed by $PH_5$ during the two years of experimentation. The lowest CEC was found where no PH was added $PH_0$ (Table 2). The profound increase in CEC due to PH in the present study highlighted the beneficial effect of HA on CEC. The HA has been reported to contain functional groups, that form the source of negative charge which could have contributed towards the CEC of the soil. The lignite brown coal are alkaline, rich in carboxylic and phenolic groups, aromatic in nature and enhanced cation exchange capacity of soil (Ali et al., 2010).

Data showed that the significantly variation were observed

Table 2: Effect of potassium humate and chemical fertilizers on physicochemical properties of soil

| Treatment | pH (1:2.5) | | EC (dSm$^{-1}$) | | Organic carbon (g kg$^{-1}$) | | CEC (C mol (p+) kg$^{-1}$) | | Bulk density (Mg m$^{-3}$) | | Water holding capacity (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Factor I NPK (%) | | | | | | | | | | | | |
| $NPK_{75\%}$ | 8.42 | 8.14 | 0.204 | 0.209 | 5.21 | 5.29 | 15.30 | 15.65 | 1.45 | 1.44 | 44.11 | 45.05 |
| $NPK_{100\%}$ | 8.37 | 8.14 | 0.228 | 0.226 | 5.49 | 5.64 | 16.23 | 16.93 | 1.43 | 1.42 | 45.45 | 46.10 |
| SEm± | 0.04 | 0.02 | 0.003 | 0.003 | 0.04 | 0.05 | 0.11 | 0.15 | 0.01 | 0.01 | 0.21 | 0.32 |
| LSD ($p$=0.05) | 0.12 | 0.06 | 0.007 | 0.009 | 0.11 | 0.15 | 0.33 | 0.45 | 0.03 | 0.02 | 0.61 | 0.94 |
| Factor II potassium humate (mg kg$^{-1}$) | | | | | | | | | | | | |
| $PH_0$ | 8.42 | 8.22 | 0.194 | 0.201 | 5.09 | 5.12 | 14.20 | 14.40 | 1.46 | 1.45 | 43.14 | 43.89 |
| $PH_5$ | 8.41 | 8.10 | 0.223 | 0.218 | 5.29 | 5.38 | 15.66 | 16.03 | 1.44 | 1.43 | 45.05 | 45.83 |
| $PH_{10}$ | 8.35 | 8.10 | 0.233 | 0.233 | 5.67 | 5.89 | 17.42 | 18.45 | 1.42 | 1.40 | 46.16 | 47.00 |
| SEm± | 0.05 | 0.02 | 0.003 | 0.004 | 0.05 | 0.06 | 0.14 | 0.19 | 0.01 | 0.01 | 0.25 | 0.40 |
| LSD ($p$=0.05) | 0.14 | 0.07 | 0.009 | 0.011 | 0.14 | 0.18 | 0.40 | 0.55 | 0.04 | 0.02 | 0.75 | 1.15 |
| Factor III Zinc sulphate (mg kg$^{-1}$) | | | | | | | | | | | | |
| $Zn_0$ | 8.43 | 8.19 | 0.215 | 0.214 | 5.29 | 5.36 | 15.38 | 15.79 | 1.44 | 1.43 | 42.89 | 43.89 |
| $Zn_{12.5}$ | 8.36 | 8.09 | 0.217 | 0.220 | 5.41 | 5.57 | 16.15 | 16.79 | 1.44 | 1.43 | 46.68 | 47.26 |
| SEm± | 0.04 | 0.02 | 0.003 | 0.003 | 0.04 | 0.05 | 0.11 | 0.15 | 0.01 | 0.01 | 0.21 | 0.32 |
| LSD ($p$=0.05) | 0.12 | 0.06 | NS | NS | 0.11 | 0.15 | 0.33 | 0.45 | NS | NS | 0.61 | 0.94 |
| Interaction | | | | | | | | | | | | |
| PH×NPK | NS | | | | S | S | NS | NS | NS | NS | NS | NS |

NPK (60-30-30 mg kg$^{-1}$ corresponding to 120, 60, and 60 kg ha$^{-1}$ of N, $P_2O_5$ and $K_2O$ respectively); PH: Potassium humate among the PH treatment and it was significantly lower bulk density (1.42 and 1.40 Mg $m^{-1}$) with $PH_{10}$ that received 10 mg $kg^{-1}$ PH and the highest bulk density (1.46 and 1.45 Mg $m^{-1}$) was observed in the pots that did not receive any $PH_0$ during first and second year of experiment respectively (Table 2). The significant reduction in bulk density was also observed with application of 5 mg $kg^{-1}$ of during both the years of experimentation (Huiet et al., 2012). The decrease in bulk density has been attributed to higher organic matter content of soil, better aggregation and increased root growth in fertilizer and organic treated plots (Sarwar et al., 2012; Bai et al., 2010; Kutuk et al., 2000).

Results showed that the WHC significantly higher was recorded (46.16 and 47.00%) with having 10 mg $kg^{-1}$ PH which was significantly higher than $PH_0$ during both the years (Table 2). The significant increase in WHC with the combination of organic sources and chemical fertilizers might be attributed to increased organic matter status of the soil and improved soil structure (Triplett et al., 1968; Sarwar et al., 2012).

Results showed that the application of PH significantly increased organic carbon (OC) in soil. The highest OC 5.67 and 5.89 g $kg^{-1}$ ($p<0.05$) was observed under $PH_{10}$ followed by $PH_5$(5.29 and 5.38 g $kg^{-1}$) during both the years of experimentation (Table 2). The positive effect might be due to the high content of organic carbon in PH itself (Bhama et al., 2003).

Data showed that the treatment $PH_{10}$ caused 17% increase in available N content in soil over $PH_0$ during first year and 18% during second year. With combined application of 100% NPK with 10 mg $kg^{-1}$ PH recorded significantly higher available N in soil during both the years (Table 3 and 4). The increase in available N might be attributed to the enhanced microbial activities induced by humic acid (Masciandaro and Ceccanti 1999). Due to the application of 10 mg $kg^{-1}$ PH resulted in 25% increase in available P content in soil over $PH_0$ during 2009 and 24% during 2010 (Figure 1). The treatment $PH_{10}\times NPK_{100\%}$ produced significantly greater available P over other treatments during both the years of experimentation (Table 3 and 4).

Meanwhile data showed that the $PH_{10}$ recorded higher exchangeable K content in soil, causing an enhancement of 16% in 2009 and 18% in 2010 over $PH_0$ (Figure 1). The interaction effect of PH with NPK was found to be significant (Table 4). The highest exchangeable K content was obtained from treatment $PH_{10}\times NPK_{100\%}$ followed by $PH_0\times NPK_{75\%}$ (Table 4). Significantly highest value of available sulphur content in

Table 3: Effect of potassium humate and chemical fertilizers on the availability of N, P, K, S and Zn in soil

| Treatment | Nitrogen (mg $kg^{-1}$) | | Phosphorus (mg $kg^{-1}$) | | Potassium (mg $kg^{-1}$) | | Sulphur (mg $kg^{-1}$) | | Zinc (mg $kg^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Factor I NPK (%) | | | | | | | | | | |
| $NPK_{75\%}$ | 108 | 110 | 11.03 | 11.98 | 125 | 130 | 9.98 | 11.02 | 0.59 | 0.63 |
| $NPK_{100\%}$ | 118 | 119 | 11.60 | 12.73 | 137 | 140 | 10.68 | 11.87 | 0.88 | 0.92 |
| SEm± | 0.80 | 0.81 | 0.08 | 0.09 | 0.62 | 0.64 | 0.10 | 0.11 | 0.01 | 0.01 |
| LSD ($p$=0.05) | 2.34 | 2.37 | 0.23 | 0.26 | 1.80 | 1.87 | 0.28 | 0.32 | 0.026 | 0.028 |
| Factor II Potassium humate (mg $kg^{-1}$) | | | | | | | | | | |
| $PH_0$ | 104 | 105 | 10.10 | 11.05 | 121 | 124 | 9.88 | 10.93 | 0.68 | 0.71 |
| $PH_5$ | 114 | 115 | 11.19 | 12.35 | 131 | 136 | 10.29 | 11.29 | 0.71 | 0.77 |
| $PH_{10}$ | 122 | 124 | 12.65 | 13.66 | 140 | 146 | 10.81 | 12.11 | 0.82 | 0.85 |
| SEm± | 0.98 | 0.99 | 0.10 | 0.11 | 0.76 | 0.78 | 0.12 | 0.13 | 0.01 | 0.01 |
| LSD ($p$=0.05) | 2.86 | 2.90 | 0.29 | 0.31 | 2.21 | 2.29 | 0.35 | 0.39 | 0.032 | 0.034 |
| Factor III Zinc sulphate (mg $kg^{-1}$) | | | | | | | | | | |
| $Zn_0$ | 111 | 112 | 10.94 | 12.02 | 128 | 133 | 10.14 | 11.18 | 0.61 | 0.65 |
| $Zn_{12.5}$ | 115 | 117 | 11.69 | 12.69 | 133 | 138 | 10.51 | 11.71 | 0.86 | 0.91 |
| SEm± | 0.80 | 0.81 | 0.08 | 0.09 | 0.62 | 0.64 | 0.10 | 0.11 | 0.01 | 0.01 |
| LSD ($p$=0.05) | 2.34 | 2.37 | 0.23 | 0.26 | 1.80 | 1.87 | 0.28 | 0.32 | 0.026 | 0.028 |
| Interaction | | | | | | | | | | |
| PH×NPK | S | S | S | S | S | S | S | S | S | S |

NPK (60-30-30 mg $kg^{-1}$ corresponding to 120, 60, and 60 kg $ha^{-1}$ of N, $P_2O_5$ & $K_2O$ respectively); PH: Potassium humate

Table 4: The interaction between chemical fertilizers and potassium humate on N, P, K, S and Zn in soil

| NPK (%) | Potassium humate (mg kg$^{-1}$ soil) | Nitrogen | | Phosphorous | | Potassium | | Sulphur | | Zinc | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mg kg$^{-1}$ | | | | | | | | | |
| | | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| 75 | 0 | 98 | 98 | 9.72 | 10.60 | 115 | 120 | 9.55 | 10.49 | 0.50 | 0.53 |
| 75 | 5 | 108 | 110 | 10.77 | 11.80 | 123 | 128 | 10.14 | 11.13 | 0.53 | 0.59 |
| 75 | 10 | 119 | 123 | 12.59 | 13.53 | 135 | 143 | 10.23 | 11.45 | 0.75 | 0.78 |
| 100 | 0 | 110 | 111 | 10.49 | 11.51 | 127 | 128 | 10.21 | 11.38 | 0.87 | 0.90 |
| 100 | 5 | 119 | 120 | 11.60 | 12.91 | 139 | 144 | 10.43 | 11.45 | 0.90 | 0.95 |
| 100 | 10 | 124 | 125 | 12.72 | 13.79 | 145 | 149 | 11.40 | 12.77 | 0.88 | 0.93 |
| LSD ($p$=0.05) | | 4.04 | 4.09 | 0.40 | 0.44 | 3.12 | 3.23 | 0.49 | 0.54 | 0.045 | 0.048 |

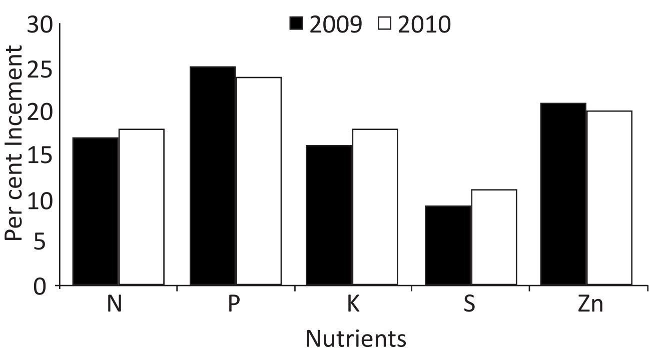


Figure 1: Per cent incement by PH10 over PH0 of N, P, K, S and Zn in soil durind 2009 and 2010

soil was recorded with 10 mg kg$^{-1}$ PH as compared to $PH_0$ and increased S content by ~9% over $PH_0$ during first year and 11% during second year (Table 3 and Figure 1). Same results were also reported by Chenghua et al., 2005; Du ZhenYu et al., 2013; Masciandaro and Ceccanti, 1999.

The application of 10 mg kg$^{-1}$ PH ($PH_{10}$) significantly ($p$< 0.05) enhanced the DTPA extractable Zn content in soil over $PH_5$ and $PH_0$. The per cent increments of DTPA extractable zinc by $PH_{10}$ over $PH_0$ were 21 during first year and 20 in second years (Figure 1). Interaction effect of PH with NPK and PH with zinc was found to be significant (Table 4) Zinc humic compounds are highly effective in increasing plant-available concentration of Zn in soils and promote plant growth under zinc deficient soil (Sharif et al., 2002; Garcia et al., 2004).

## 4. Conclusion

There was an enrichment of available N, P, K and Zn in the soil supplemented with mineral fertilization, PH and Zn-sulphate. PH also increased soil fertility indicators such as the BD, WHC and the CEC and had significantly influenced soil physical properties. Application of 10 mg kg$^{-1}$ PH along with 100% RDF and 12.5 mg kg$^{-1}$ zinc sulphate caused significant increase N, P, K, S and Zn content in soil as compared to 100% and 75% NPK alone.

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