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RESEARCH PAPER

Effect of potassium fertilizer integrated with humic acid and cattle manure on tomato attributes and soil properties

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Key Message: This study focuses on potassium dynamics of soil when integrated with humic acid and cattle manure and its effect on tomato crop. The integrated use of potassium with the organic manure improved the different traits of tomato and soil properties.

Abstract: Potassium (K) integration with humic acid (HA) and cattle manure (CM) was investigated on tomato for growth, yield and quality along with their effect on soil physico-chemical characteristics. A pot culture experiment was designed including organic manures and K levels as two variable factors. Significantly higher number of fruits per plant and fruit weight were recorded in the plant parameters, while soil and quality parameters also showed significant effect of treatments. The tomatoes per plants were counted highest in number where HA in combination with potash @ 200 kg ha^{-1} was applied. The weight of fruits was found to be greater in pots of CM fortified with potassium @ 150 kg ha^{-1}. The soil pH decreased with the increase in potassium fertilizer, but this decrease was buffered in the organic amendment pots as compared with the control. Soil bulk density was significantly decreased by the addition of organic amendments. The extractable potassium in the soil was also increased in the pots where potassium was used with the organic manures. Among qualitative parameters; total soluble solids (TSS) was greater in the organic treatments in contrast with the control. From the results of this study, it can be concluded that application of organic amendments along with 150 kg K ha^{-1} exhibited superior results for various traits of tomato and also proved to be effective in improving the soil physico-chemical characteristics. There is a need to carry out further research using the same treatments with the organic manures under field conditions.

Keywords: Cattle manure, Humic acid, Potassium, Quality, Tomato, Yield

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Introduction

Potassium is an important plant nutrient required in relatively large quantities. It is considered as an essential element for growth, quality and yield of crops because it is involved in various physiological functions. Potassium is considered an imperative in the process of photosynthesis, increases the activity of important enzymes, and has a role in nutrient cycling. Another most important role is the protection of plants from moisture stress. Potassium is an important nutrient for controlling turgor and avoiding losses of water and preventing the plants from wilting (Dinçsoy & Sonmez, 2019). Despite these important functions, farmers in Pakistan rarely apply this nutrient and consider it as abundant in soil. The depletion of potassium from soil is rapid as it is removed from soil by crops in greater quantity and added in very small amounts. Potassium in soil exists in different forms, the most common is non – exchangeable K and the least is solution K which is available to the plants.

In conventional farming, the use of different organic materials such as cattle manure, poultry manure and compost etc. provide plant nutrients to the soil, improve physico-chemical properties of soil and enhance microbial activities. Although, organic materials are considered as the store house for nutrients but these nutrients are not readily available to the plants. Integration of inorganic fertilizers with organic showed better results for crops especially vegetables. It has been reported that potassium losses may be reduced when applied with humic acid (Rosolem et al., 2017). Also, other researchers have reported that uptake of potassium in the grains significantly increased when applied with the farmyard manure (Ranpariya et al., 2017).

In recent years, humic substances have been widely used as organic substances with natural ligands in the edaphic environment. Different organic fractions are used at different rates, by different researchers and some have investigated that one kilogram of humic acid may be used as an alternative for one metric tonne of cattle manure (Tahir et al., 2011; Humintech, 2012). The significance of using humic acid can be understood from the fact that it is used as a good soil conditioner and supplement along with inorganic fertilizer. Humic acid has complex nature with higher exchange capacity and chelating characteristics. It has the capacity to store essential nutrients, enhance microbial activities, improve nutrient assimilation and enhance root vigor (Sharif et al., 2005; Radwan et al., 2015). Moraditochaee (2012) reported that humic acid has significance in root growth and enhancing nutrients and water uptake in the vegetable crops. Under stress, the harmful effects are reduced (Unlu et al., 2011).

Tomato is a very important kitchen staple vegetable used in daily cooked food. It is highly nutritious and contributes to a healthy diet. It serves as a rich source of sugar, protein, vitamins and food fibers. Tomato requires potassium for its qualitative traits i.e. lycopene content and pigment synthesis. An estimated one tonne production of tomato requires K @ 2.35 – 3.26 kg. Tomato has greater financial value amongst the other vegetables grown in Pakistan. The total cultivated area under this vegetable during 2017 was 63.20 thousand hectares with a total produce of 601.098 thousand tonnes (Food and Agriculture Organization [FAO], 2017). Keeping in view the importance of potassium and humic acid, the current study was designed with tomato as a test crop, and its yield and quality was determined by applying different levels of potassium and organic amendments. Moreover, the soil characteristics were also examined.

Materials and Methods

To evaluate the efficacy of inorganic potassium fertilizers applied with organic amendments (cattle manure and humic acid), a pot experiment was conducted at Department of Soil Science, Gomal University, Dera Ismail Khan, Pakistan. The experiment consisted of the integrated use of manures with potassium levels in a complete randomized design with four replications. Cattle manure and humic acid were applied @ 10 tonnes ha^{-1} and @ 5 kg ha^{-1}, respectively. The treatments used in the experiment were Control (Without K_2O), 50 kg K ha^{-1}, 100 kg K ha^{-1}, 150 kg K ha^{-1}, 200 kg K ha^{-1}. The earthen pots of size 19965 cm^3 were filled with 20 kg dry soil of texture sandy clay loamy. Tomato variety Rio Grande was sown in November, 2018 and after establishing of nursery was transferred to the pots in first week of February, 2019. In all the pots, nitrogen and phosphorus were applied @ 160 and 120 kg ha^{-1} respectively. Irrigation, pesticide and fungicide were applied at a constant rate to all the pots.

Soil analysis

Analysis of composite soil sample prior to the experiment and after the harvest of tomato from each pot was completed. Soil texture was measured through hydrometric method given by Koehler et al. (1984), soil $pH_{1:5}$ was determined using pH meter (Mclean, 1982) and soil electrical conductivity was measured using Inolab EC meter (Richards, 1954). Soil bulk density was measured by core sampler (Blake & Hartge, 1986), soil organic matter using the potassium chromate solution through titration method (Nelson & Sommers, 1982) and soil potassium was found in the soil sample by Flame photometer using the procedure given by Soltanpour and Workman (1979).

Pre–analysis of experimental soil

The pre-analysis of experimental soil showed that the soil fractionation was sandy clay loam, with bulk density value of 1.39 g cm^{-3} and porosity was 52.45%. The chemical characteristic showed that the soil was non saline with electrical conductivity of 0.90 dSm^{-1} and pH of 7.30. The soil was low in organic matter contents and total nitrogen. The extractable phosphorus and potassium measured was recorded 5.81 and 155 mg kg^{-1}, respectively (Table 1).

Table 1 Physico-chemical properties of soil before experiment

Soil parameters	Unit	Value
Soil texture	-	Sandy clay loam
Bulk density	gcm^{-3}	1.39
Porosity	%	52.45
pH (1:5)	-	7.30
Electrical conductivity (1: 5)	μScm^{-1}	906
Organic matter	%	0.31
Total nitrogen	%	0.015
Extractable phosphorus	mg kg^{-1}	5.81
Exchangeable potassium	mg kg^{-1}	155

Plants parameters

Chlorophyll contents (µg cm^{-2}) were determined in ten leaves selected from the treatment using the SPAD-502 reading (Xiong et al., 2015). Plant height (cm) was determined using the meter rod. Fruit diameter (cm) was calculated using Vernier caliper, Number of fruits $plant^{-1}$ were calculated after taking the average number of fruits produced after maturity. The fruit weight (g) was calculated by taking the average of 10 fruits harvested. The qualitative parameters including the fruit pH was calculated from tomato paste by the pH meter and total soluble solids (TSS) were determined using the refractometer at maturity of crop.

Statistical analysis

Statistical analysis was carried out using the procedure devised by Steel et al. (1997). Comparison of treatment means was done by calculating the least significance difference (LSD) using statistical software Statistics 8.1.

Results and Discussion

Effect of potassium levels and organic amendments on chlorophyll contents

The leaf chlorophyll contents determined by the SPAD meter showed non-significant variation amongst the means of pots receiving both the treatments i.e. manures and K fertilizer (Table 2). The highest chlorophyll contents of 53.96 µg cm^{-2} were recorded in the humic acid pots in combination with 120 kg ha^{-1} potassium fertilizer. The least was measured 43.63 µg cm^{-2} in control (without organic manures and potassium fertilizer). Similar findings have been reported by Al-Moshileh et al. (2017) with statistically non-significant impact of potassium levels used in increasing concentrations of potassium fertilizer. It has been reported by other researchers that chlorophyll contents were influenced by the potassium due to its role in stomatal regulation. Naz et al. (2018) recorded an enhancement in leaf chlorophyll contents of tomato by the addition of foliar NPK with FYM @ 5 t ha^{-1}. Similar to our findings, Abd El–Razek et al. (2012) reported a significant impact of humic acid on chlorophyll contents, it was further revealed that it enhanced the nutrients uptake by plants.

Effect of potassium levels and organic amendments on plant height

The results pertaining to the plant height (cm) of tomato showed that addition of the potassium levels and organic manure was non-significantly changed (Table 3). However, the tallest plants of 32.0 cm were observed in the humic acid treated pots without potassium. The shortest plants of 24 cm were measured in the cattle manure pots without K fertilizer. The height of plant may have been limited to a certain height as the experiment was conducted in a micro – environment of pot and also as plant height is a trait related to the genetic makeup and there is homogeneity amongst the plants of same verities. Plant height is considered as a genetic assortment of a genotype (Shahzad et al. (2007). In contrast to our findings, Kazemi (2013) have found variation amongst the height of plants of tomato by the use of humic acid.

Effect of potassium levels and organic amendments on fruit diameter

The fruit diameter (cm) recorded after the harvest of tomato as influenced by the potassium dosage and organic amendments i.e. humic acid and cattle manure showed non-significant difference amongst the means at 5% level of significance (Table 3). Fruit diameter increased with the increment of inorganic potassium fertilizer in the control pots where neither of the organic amendments was used. Researchers have shown different results pertaining to the application of organic manure with the inorganic K fertilizer. Islam et al. (2013) showed a significant influence of FYM in combination with potassium fertilizer on the fruit diameter. Further they have narrated that the fruit diameter of tomato fertilized with inorganic K was higher than the organic amendments used solely.

Effect of potassium levels and organic amendments on number of fruits $plant^{-1}$

The fruits per plant were significantly ($P<0.05$) changed by the combined application of K levels with organic amendments. The maximum fruits per plant (51.3) were found in the pots where HA was added along with K @ 200 kg K ha^{-1} (Table 4). These were at par with the pots receiving HA + K @ 100 kg ha^{-1}. Fruits were recorded least in control pots where neither K nor organic amendments were used. Similar findings by Javaria et al. (2012a) showed that potassium used at increasing level enhanced the number of fruits $plant^{-1}$. Also, Samiullah and Khan (2003) reported the influence of potassium on the number of fruits which was recorded almost double, the reason reported was the influence of potassium on the physiological processes i.e. photosynthesis, activation of enzymes etc. (Tsialtas & Maslaris, 2009). Abdellatif et al. (2017) reported the highest number of fruits per plant by the use of humic acid. Jagadeesha (2008) also found that the use of biofertilizer in combination with the mineral fertilizers resulted in significantly higher number of fruits of tomato when compared with control.

Table 2 Effect of potassium levels and organic amendments on chlorophyll contents

Treatments	Chlorophyll contents (µ g cm^2)		
	CM	HA	Control
Without K	47.93^{NS}	50.30^{NS}	43.63
50 kg K ha^{-1}	53.06	49.00	42.70
100 kg K ha^{-1}	51.00	50.26	52.96
150 kg K ha^{-1}	47.80	53.96	53.90
200 kg K ha^{-1}	51.00	49.23	53.60

The values with different letters in a column are significant at 5% level of significance; NS: Non-significant; CM: Cattle manure; HA: Humic acid

Effect of potassium levels and organic amendments on fruit weight

In current study, the addition of potassium with humic acid and cattle manure showed the significant effect on the average tomato fruit weight (g) (Table 4). The highest weight of tomato was recorded 33.99 g in the pots where potassium @ 150 kg ha^{-1} without any organic amendments was applied, statistically similar weight of tomato in the rest of treatments found except for control where no K was added and those receiving sole humic acid. The least weight was recoded 26.09 g in control, without K and organic amendments. The weight of tomato increased with the increasing level of K fertilizers. Woldemariam et al. (2018) reported increase in fruit weight of tomato by the increased use of potassium fertilizer, but beyond 150 kg K_2O ha^{-1} the fruit weight started to decline. Bilalis et al.

(2018) found that fruit weight was significantly higher in the inorganic fertilizer as compared with organic amendments and control. Ghourab et al. (2000) concluded that potassium applied in combination with manure enhanced the weight of fruits. The use of K increases the photosynthesis process and also increases the efficiency of water used by the plants which contributes to the greater weight of fruits. Application of humic acid with inorganic fertilizer increased the yield of crop by 11-21% under calcareous soil having high soil pH (Khan et al., 2018).

Effect of potassium levels and organic amendments on soil pH

The application of organic amendments with potassium levels showed the significant effect on soil pH ($P<0.05$). Both HA and CM were effective in reducing the pH with increased potassium level @ 200 kg ha^{-1}. The least value was recorded 7.85 and 7.96, respectively (Table 5). In the control pots, the pH was 8.73, the highest amongst treatments. It has been reported by Dikinya & Mufwanzala (2010) that the application of poultry manure non-significantly affected the soil pH. Azeez and Van Averbeke (2012) recorded greater soil pH by the application of cattle manure as compared with poultry and goat manures. Dincsoy and Sonmez (2019) found that interaction of potassium with humic acid have caused significant decrease in soil pH.

Effect of potassium levels and organic amendments on bulk density

The results pertaining to soil bulk density revealed that manures integrated with potassium levels reduced the soil bulk density at 5% level of significance. Both the organic amendments were effective in improving the bulk density. The least value of bulk density 1.01 g cm^{-3} was found in cattle manure (Table 5). The highest bulk density of 1.71 g cm^{-3} was recorded in the pots where potassium was applied alone @ 50 kg K ha^{-1}. Similar reduction in the value of bulk density by the application of sole FYM and along with commercial potassium fertilizer of 9.72% and 15.56 %, respectively, when compared with commercial fertilizer alone (Meena et al., 2018). Schjonning et al. (1994) revealed that decrease in bulk density may be attributed to soil aggregation by the application of organic amendments. Similarly, Khan et al. (2016) reported the significant increase in soil porosity and reduction in bulk density by the application of FYM combined with commercial fertilizer.

Effect of potassium levels and organic amendments on soil organic matter

The soil organic matter (%) as influenced by the organic amendments and inorganic potassium fertilizers showed non-significant difference (Table 6). However, the use of cattle manure and humic acid treated pots showed greater organic matter contents as compared control treated pots. The highest organic matter (0.98%) was recorded in the humic acid treated pots along with potassium fertilizer @ 100 kg K ha^{-1}. The lowest percent organic matter was recorded in control without any organic amendments and potassium fertilizer. The significant effect on soil organic matter by the application of organic amendments may be observed in a long-term field experiments as Subhan et al. (2017) carried out an experiment for two consecutive years and found a significant increase in organic matter by the application of cattle manures. Similarly, Gumus and Şeker (2015) revealed that the use of humic acid has significantly improved the soil organic matter contents. Yunilasari et al. (2020) reported an increase in soil organic carbon by the application of biochar in combination with cattle manure @ 10 t ha^{-1} but the increase was non-significant when compared with the rest of the treatments.

Effect of potassium levels and organic amendments on extractable potassium

Extractable potassium was significantly affected by the use of potassium integrated with organic amendments (Table 6). The maximum extractable potassium (209.27 mg kg^{-1}) was recorded in the treatments with dosage of HA + 200 kg ha^{-1}. While the least potassium was measured (153.90 mg kg^{-1}) in control. The increasing level of potassium along with the organic amendment showed greater soil extractable potassium over control. The results were in agreement with the findings of Han et al. (2016) who showed greater soil potassium in the treatments where organic amendments were applied with potassium fertilizer. Waheed et al. (2015) also found an enhancement of potassium in soil by the application of potassium with organic amendments. Similarly, Qian et al. (2005) reported the significant increase in extractable K by the application of animal manure at higher rate over control.

Effect of potassium levels and organic amendments on fruit pH

Effect of combined application of manure and potassium levels on fruit pH was non-significant ($P<0.05$). It was apparent from the results that fruit pH was retained at 4.00. However, the increasing level of inorganic fertilizer resulted in lower fruit pH (Table 7). In connection with current results, Khan et al. (2013) also obtained non-significant value for fruit pH by the use of potassium level and FYM and their interaction. Similarly, non-significant effect on fruit pH of tomato was reported by the addition of organic substances including cattle and goat manure (El-Tantawy, 2009). Also, non-significant effects on fruit pH by the use of inorganic fertilizer along with different manures have been observed by Meaza et al. (2007).

Effect of potassium levels and organic amendments on fruit total soluble solids

Total soluble solids (TSS) (%) showed a significant variation amongst the means by the addition of manures and K levels in combination (Table 7). The greater TSS was found 5.33% in the treatment of K @ 200 kg ha^{-1} along with CM, the results were statistically similar to the pots where HA with the highest level of K was applied. The least value for TSS was 2.72% recorded in pots where no K was applied. Our findings were according to the results of other researchers who found the enhancement of TSS value with the use of organic amendments and also by the application of inorganic K fertilizers (Ibrahim & Fadni, 2012: Javaria et al., 2012b). Fanasca et al. (2006) also found the highest value for TSS in the nutrient solution containing potassium.

Conclusion

It was concluded from this study that integrated use of humic acid with the higher concentration of potassium gave better response of tomato in terms of growth, yield and quality. The soil properties were also improved with the use of humic acid. The cattle manure was also comparable in greater quantity with the humic acid.

Author Contribution Statement: Muhammad Ibrahim executed the research study. Qudrat Ullah Khan and Muhammad Jamil Khan guided, supervised and wrote the manuscript. Iftikhar Ali, Muhammad Riaz and Saleemullah helped in analyzing the soil samples in laboratory and data collection. Muhammad Mamoon ur Rashid and Asif Latif carried out the statistical analysis and helped in manuscript writing.

Conflict of Interest: The authors declare that they have no conflict of interest.

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Table 3 Effect of potassium levels and organic amendments on plant height and fruit diameter

Treatments	Plant height (cm)			Fruit diameter (cm)		
	CM	HA	Control	CM	HA	Control
Without K	24.0 ^{NS}	32.0	25.6	2.53 ^{NS}	2.41	2.92
50 kg K ha^{-1}	27.6	28.3	25.3	2.94	3.77	3.12
100 kg K ha^{-1}	24.0	30.0	26.0	3.03	2.62	4.11
150 kg K ha^{-1}	28.6	26.0	29.3	3.71	2.69	4.15
200 kg K ha^{-1}	26.6	28.3	26.2	2.79	4.36	4.39

The values with different letters in a column are significant at 5% level of significance; NS: Non–significant; CM: Cattle manure; HA: Humic acid

Table 4 Effect of potassium levels and organic amendments on number of fruit plant^{-1} and fruit weight

Treatments	Number of fruit plant^{-1}			Fruit weight (g)		
	CM	HA	Control	CM	HA	Control
Without K	30.00^{de}	27.20^{de}	21.10^{f}	28.35^{ab}	26.24^{b}	26.09^{b}
50 kg K ha^{-1}	31.50^{de}	42.60^{bc}	29.40^{de}	28.88^{ab}	28.84^{ab}	28.58^{ab}
100 kg K ha^{-1}	41.07^{b}	47.04^{ab}	44.10^{bc}	31.91^{ab}	31.85^{ab}	32.15^{ab}
150 kg K ha^{-1}	45.67^{b}	39.66^{c}	43.20^{bc}	33.70^{a}	33.92^{a}	33.99^{a}
200 kg K ha^{-1}	39.04^{c}	51.30^{a}	32.00^{d}	32.15^{ab}	30.83^{ab}	31.14^{ab}

The values with different letters in a column are significant at 5% level of significance; NS: Non–significant; CM: Cattle manure; HA: Humic acid

Table 5 Effect of potassium levels and organic amendments on soil pH and soil bulk density

Treatments	Soil pH			Soil bulk density (g cm^{-3})		
	CM	HA	Control	CM	HA	Control
Without K	8.21^{ab}	8.53^{ab}	8.73^{a}	1.45^{abc}	1.05^{bc}	1.35^{abc}
50 kg K ha^{-1}	8.00^{b}	8.64^{ab}	8.31^{ab}	1.31^{abc}	1.40^{abc}	1.71^{a}
100 kg K ha^{-1}	8.65^{ab}	8.68^{a}	8.62^{ab}	1.13^{bc}	1.41^{abc}	1.34^{abc}
150 kg K ha^{-1}	7.98^{b}	8.46^{ab}	8.46^{ab}	1.38^{abc}	1.12^{bc}	1.62^{a}
200 kg K ha^{-1}	7.96^{b}	7.85^{b}	8.16^{ab}	1.45^{ab}	1.42^{abc}	1.63^{a}

The values with different letters in a column are significant at 5% level of significance; NS: Non–significant; CM: Cattle manure; HA: Humic acid

Table 6 Effect of potassium levels and organic amendments on soil organic matter and extractable potassium

Treatments	Soil organic matter (%)			Extractable potassium (mg kg^{-1})		
	CM	HA	Control	CM	HA	Control
Without K	0.65	0.72	0.51	156.03^{e}	168.23^{cd}	153.90^{e}
50 kg K ha^{-1}	0.97	0.80	0.65	156.70^{e}	164.60^{cde}	160.63^{de}
100 kg K ha^{-1}	0.87	0.98	0.75	158.43^{de}	190.37^{abc}	157.80^{e}
150 kg K ha^{-1}	0.93	0.66	0.74	193.23^{abc}	163.80^{cde}	169.03^{b-e}
200 kg K ha^{-1}	0.90	0.82	0.62	198.43^{ab}	209.27^{a}	175.87^{b-e}

The values with different letters in a column are significant at 5% level of significance; NS: Non–significant; CM: Cattle manure; HA: Humic acid

Table 7 Effect of potassium levels and organic amendments on soil organic matter and extractable potassium

Treatments	Fruit pH			Total soluble solids (%)		
	CM	HA	Control	CM	HA	Control
Without K	4.15 ^{NS}	4.07	4.00	3.16^{b}	3.84^{ab}	2.72^{b}
50 kg K ha^{-1}	4.01	4.13	3.93	3.23^{b}	3.27^{b}	2.89^{b}
100 kg K ha^{-1}	4.02	4.05	3.85	3.43^{b}	3.70^{ab}	3.39^{b}
150 kg K ha^{-1}	3.95	4.10	3.86	3.30^{b}	4.00^{ab}	3.24^{b}
200 kg K ha^{-1}	3.92	4.09	3.82	5.33^{a}	5.19^{a}	3.43^{b}

The values with different letters in a column are significant at 5% level of significance; NS: Non–significant; CM: Cattle manure; HA: Humic acid

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