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APPLICATION OF POTASSIUM HUMATE FOR IMPROVING THE GROWTH AND YIELD OF WHEAT

Shuaib Kaleem*[1] • Wajid Nasim[2] • Muhammad Tariq[3] • Saeed Ahmad[1] • Muhammad Younas Ahmedani[4]

AUTHOR'S AFFILIATION

[1]Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan
[2]COMSATS Institute of information Technology, Vehari, Pakistan
[3]Department of Agronomy, College of Agriculture, Ghazi University, Dera Ghazi Khan, Pakistan
[4]Department of Agronomy, College of Agriculture, University of Sargodha, Sargodha, Pakistan
*Corresponding author's e-mail: shuaibkaleem70@gmail.com

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ABSTRACT

Background Potassium humate (K-humate) might be important for improving crop productivity and soil health, particularly in arid and semiarid regions. Intensive cropping and inadequate addition of plant nutrients have depleted the soil fertility, leading to poor crop yield and quality. The present study was designed to evaluate the effect of different levels and mode of application of K-humate on wheat productivity.

Methodology The field experiments were conducted at two different sites (Farmer's field and research farm) under Agro-ecological conditions of Dera Ghazi Khan, Punjab, Pakistan during Rabi 2015-16. The experimental treatments were; T_0: Control, T_1: 3 Foliar spray of K-humate at 25 days after sowing, T_2: K-humate @ 25 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing, and T_3: K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing using simple randomized complete block design with three replications. Plot size of 153.31 and 141.75 m^2 for site-1 and site-2 was maintained, respectively. Seed rate of 125 kg ha^{-1} was used and sowing was done by drill method. Recommended dose of nitrogen, phosphorus and potassium (128: 114: 62 kg ha^{-1}) was applied.

Results Data about growth and yield attributes like germination count m^{-2}, number of fertile tillers m^{-2}, number of spikelets $spike^{-1}$, plant height at maturity, spike length, number of grains $spike^{-1}$, 1000-grain weight and grain yield were recorded. It was found that all these plant growth and yield attributes were significantly ($p \leq 0.05$) affected by varying K-humate application levels and methods. Maximum productive tillers m^{-2}, number of grains $spike^{-1}$, plant height, number of spikelets per spike, spike length, 1000-grain weight and grain yield were produced when K-humate @ 50 kg ha^{-1} at sowing + 3 foliar sprays of K-humate at 25 days after sowing were applied. Whereas, minimum values of yield parameters were recorded in case of control (T_0).

Conclusion Based on the results, it is concluded that application of K-humate @ 50 kg ha^{-1} at sowing time + 3 foliar sprays of K-humate at 25 days after sowing could significantly be improved the grain yield of wheat under the agro-climatic conditions of Dera Ghazi Khan, Pakistan.

INTRODUCTION

Agriculture sector in Pakistan contributes about 5.4% to gross domestic production and provides employment to 45% of labor force in the country (Anonymous 2016). Among the cereals, wheat (*Triticum aestivum* L.) is the staple food for a population of almost 1.5 billion in the world (Kilic and Yagbasanlar 2010). It is the most valuable cereal crop in Pakistan by contributing 25.6% to the value added in agriculture with the total production of 2.7 thousand kg ha^{-1} (Anonymous 2016). According to Zakaria et al. (2013), wheat is the most important and widely grown cereal crop worldwide through its uses as grains, straw and bakery products. Wheat flour and whole cereal grain is a rich source of phosphorus, potassium, magnesium, calcium, sodium and iron (Ragaee et al. 2006). Increase in grain yield of wheat is an important

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national task to meet the continuous increasing food demands of Pakistan population.

Many efforts have been made to increase the wheat productivity through the use of high yielding wheat varieties, appropriate plant protection, synthetic fertilizers, plant growth enhancers and different growth promoting extracts, but these efforts have limited success for getting the potential yield of wheat. Application of humic acid to improve the crop growth and productivity has been well documented (Yildirim 2007). Humic acid is an organic bio-stimulant compound that significantly increases the crop yield by improving plant growth and development. It also improves physical, chemical and biological properties of soils (Bakry et al. 2013). Application of potassium humate (K-humate) can significantly increase the yield and yield components in cereal crops (Dileep and Singh 2017). The role of humic acid is well known in controlling soil borne diseases, improving soil health, increasing nutrient availability and uptake by plants, and consequently plant growth and yield (Mauromicale et al. 2011). According to Sahar and Nejad (2014), higher dose of humic acid can be more effective to improve the growth and yield attributes of crop plants. Humic acid has also been reported to reduce the toxic effect of salts on different crops including wheat (Khan et al. 2010), rice (Saha et al. 2013), corn (Khaled and Fawy 2011), millet (Saruhan et al. 2011), rapeseed (Keeling et al. 2003), turnip (Albayrak 2005) and mung bean (Waqas et al. 2014). The use of humic acid as a stable fraction of carbon can improve the biochemical properties of soil including the water holding capacity, soil fertility, buffering of pH, thermal insulation and nutrient use efficiency, all these ultimately improve plant growth and yield (Fahramand et al. 2014). Humic acid also assimilates minor and major elements, enhances protein synthesis and activates biomass production which stimulates plant growth (Haroon et al. 2010). Delfine (2005) reported an increase in seedling growth and root development in wheat due to the application of humic acid. Cimrin and Yilmaz (2005) are of the view that humic acid not only improves yield but also phosphorus content of the plant.

Plant physiological aspects are highly sensitive to environmental factors and are, therefore, responsible in determining plant growth and yield. One approach toward the understanding of physiological responses to the environment is to follow the series of events after growth initiates by humic acid applications. Keeping in view the above discussion, a study was conducted to evaluate the effects of various K-humate application levels and methods on growth and yield of wheat under agro-ecological conditions of Dera Ghazi Khan.

MATERIALS AND METHODS

Field experiments were conducted to evaluate the effectiveness of different levels and application mode of K-humate on growth and yield of wheat at two different sites i.e. Mauza Mallana, Dera Ghazi Khan (site-1) and Adaptive Research Farm, Rakh Chabri Dera Ghazi Khan (site-2), Punjab, Pakistan during Rabi season of 2015-16. The experiment was carried out using simple randomized complete block design with three replications. Experimental plan was comprised of four treatments including T_0: Control, T_1: 3 Foliar spray of K-Humate at 25 days after sowing, T_2: K-humate @ 25 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing and T_3: K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing. Plot size was 153.31 m^2 at site-1 and 141.75 m^2 at site -II. Wheat cultivar "Faisalabad-2008" was planted @ 125 kg ha^{-1} by drill method. Nitrogen, phosphorus and potassium were applied @ 128-114-62 kg ha^{-1} at both locations in the form of urea, triple super phosphate and sulfate of potash. Nitrogen fertilizer was applied in three splits; one-third nitrogen while full dose of phosphorus and potash were applied at the time of seedbed preparation. K-humate with 98% concentration was applied to soil while, K-humate solution having 0.5% concentration was applied as foliar spray according to treatment plan. The second split of nitrogen was applied at the time of first irrigation and 3rd at the time of 3rd irrigation. Canal water was used for irrigation and all other agronomic practices were kept uniform at both sites. Selected physicochemical properties of experimental soil are presented in Table 1.

Data regarding germination count m^{-2} , number of productive tillers m^{-2}, spike length, plant height, number of grains $spike^{-1}$, number of spikelets $spike^{-1}$, 1000-grain weight and grain yield were recorded from each experimental unit at both sites by following standard procedure. All data were statistically analyzed using Fisher's analysis of variance techniques. For obtaining significant differences, least significant difference test was used for comparison among the treatment means (Jan et al. 2009).

Table 1 Physicochemical properties of experimental sites

Soil properties	**Value**	
	Site - I	**Site - II**
Soil texture	Loam	Loam
Saturation percentage	32	30
Electrical conductivity (dS m^{-1})	3.10	3.14
Soil pH	7.40	8.10
Organic matter (%)	0.28	0.10
Available soil P (mg kg^{-1})	6.0	4.00
Extractable soil K (mg kg^{-1})	215.0	88.0

RESULTS AND DISCUSSION

Germination count

Data regarding germination count are mentioned in Table 2. Germination count (seedlings m^{-2}) was significantly ($p \leq 0.05$) affected by K-humate application. The maximum wheat germination count of 214.56 seedlings m^{-2} at site-I and 211.23 seedlings m^{-2} at site-II were recorded by the application of 25 kg K-humate ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing (T_2), and it was at par with T_3 (K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing). While, minimum germination count of 205.90 seedlings m^{-2} at site-1 and 203.56 seedlings m^{-2} at site-II, were observed in plots treated with only 3 foliar applications of K-humate at 25 days interval after sowing (T_1) and it was at par with control (T_0). Khaled and Fawy (2011) reported higher germination in humic acid applied soils. Delfine (2005) and Tufail et al. (2014) have also reported higher germination along with an increase in number of plants when humic acid was applied to wheat crop.

Productive tillers count

Higher number of productive tillers (319.31 m^{-2} at site-I and 284.83 m^{-2} at site-II) were recorded by the application of K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of foliar K-humate at 25 days interval after sowing (Table 2). The productive tillers m^{-2} at site-I were statistically at par with the number of productive tillers produced by the treatments $T_{2,}$ while minimum productive tillers m^{-2} were observed in control plots (without K-humate application. These results are similar to the findings of Khan et al. (2010) and Bakry et al. (2013) who reported that application of humic acid increased the number of tillers per unit area. A similarly increase in productive tillers per unit area was reported by Sahar and Nejad (2014) with higher dose of humic acid.

Plant height

Plant height at maturity is a function of combined effects of genetic make-up and environmental factors. Plant height at maturity showed statistically significant ($p \leq 0.05$) differences among the treatments (Table 2). At site-I, maximum plant height (100 cm) was recorded in plots treated with T_3 (K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing). Similar trend was also found at Site-2 which depicted that higher dose of K-humate could enhance cell division and cell elongation, ultimately causing an increase in plant height. These results are in conformity with the findings of Delfine (2005) and Sahar and Nejad (2014) who found that higher dose of humic acid greatly enhanced plant vigor and exposure, thus increased plant height.

Spike length

The data relating to spike length as influenced by different K-humate application levels and methods is presented in Table 2. Results about spike length at maturity showed significant ($p \leq 0.05$) differences among different treatments. Maximum spike length (12.75 cm) was recorded in plots treated with T_3 (K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing) at site-1 as compared to control (T_0) where spike length was 10.19 cm. Similar trend was also found at site-2, which depicted that higher dose of K-humate could affect growth process by enhancing cell division and cell extension, ultimately causing an increase in spike length. A very similar results were reported by Delfine (2005), Bakry et al. (2013) and Sahar and Nejad (2014) who found that higher dose of humic acid greatly influenced the plant photosynthetic activity due to better nutrition, thus increased spike length.

Number of spikelets per spike

Data regarding number of spikelets per spike at maturity showed statistically significant ($p \leq 0.05$) differences among the different treatment means (Table 3). At site-I, maximum number of spikelets per spike (18.55) were recorded in plots treated with T_3 (K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing) as compared to untreated control (T_0) where number of spikelets per spike was recorded as 13.65. Similar trend was also observed at site-II. These results revealed that higher dose of K-humate could affect photosynthates production which might be responsible for increasing spike length and number of spikelets per spike. In a similar experimentation by Delfine (2005) and Bakry et al. (2013) found that higher dose of humic acid greatly influenced the plant growth and yield processes, plant vigor and increased spike length and number of spikelets $spike^{-1}$. Similarly, Dileep and Singh (2017) also found that application of K-humate significantly ($p \leq 0.05$) increased yield and yield components of cereal crops.

Number of grains per spike

Number of grains per spike were considerably influenced by the application of K-humate (Table 3). Maximum grains per spike (34.41 and 41.06) were obtained from site-I and site-II, respectively when K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing was applied (T_3). While, treatments (T_1, T_2 and T_3 at site-I) showed non-significant ($p \leq 0.05$) effect on number grains $spike^{-1}$ to each other. Three foliar spray of K-humate at 25 days

Table 2 Effect of different levels of K-humate on growth and yield attributes of wheat at two locations in arid climate of Dera Ghazi Khan, Pakistan

Treatments	**Germination m^{-2}**		**Productive tillers m^{-2}**		**Plant height (cm)**		**Spike length (cm)**	
	Site-I	**Site-II**	**Site-I**	**Site-II**	**Site-I**	**Site-II**	**Site-I**	**Site-II**
T_0	208.90ab	205.56bc	312.31ab	281.50bc	91.32c	82.53c	10.19b	10.52ns
T_1	205.90b	203.56c	306.31b	279.50c	96.04b	85.10b	11.70ab	10.78
T_2	214.56a	211.23a	322.31a	282.17b	98.40a	90.21a	12.22a	11.01
T_3	210.90ab	207.90ab	319.31a	284.83a	100.10a	92.23a	12.75a	11.19
LSD value (0.05%)	3.920	5.326	7.141	2.362	2.291	2.260	0.922	

Treatment means sharing same letter(s) in a column indicates non-significant differences. T_0: Control, T_1: 3 Foliar spray of K-humate at 25 days after sowing, T_2: K-humate @ 25 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing and T_3: K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing

Table 3 Effect of different levels of K-humate on yield and yield attributes of wheat at two locations in arid climate of Dera Ghazi Khan, Pakistan

Treatments	**Number of spikelets $spike^{-1}$**		**Number of grains $spike^{-1}$**		**1000-Grain weight (g)**		**Grain yield (kg ha^{-1})**	
	Site-I	**Site-II**	**Site-I**	**Site-II**	**Site-I**	**Site-II**	**Site-I**	**Site-II**
T_0:	13.65d	11.00c	29.42b	37.81c	39.60c	37.79b	3642.10c	4022.70c
T_1	14.70c	12.70b	34.15a	39.62b	40.43bc	39.23a	4230.80b	4381.90b
T_2	16.22b	13.10a	32.61a	39.58b	41.22ab	39.58a	4331.30b	4458.90ab
T_3	18.55a	14.26a	34.41a	41.06a	42.57a	38.72ab	4675.10a	4566.50a
LSD value (0.05%)	0.927	0.789	1.842	1.422	1.855	0.226	123.10	1.875

Treatment means sharing same letter(s) in a column indicates non-significant differences. T_0: Control, T_1: 3 Foliar spray of K-humate at 25 days after sowing, T_2: K-humate @ 25 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing and T_3: K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days after sowing

interval after sowing and T_2 (K-humate @ 25 kg ha^{-1} at sowing + foliar 3 spray of K-humate at 25 days interval after sowing) produced 34.15 and 32.61 number of grains per spike, respectively at site-I which were statistically at par to the number of grains per spike produced in plots treated with T_3 at site-II. However, minimum number of grains per spike (29.42, 37.81 from site-I and II, respectively) were observed without K-humate application (T_0). These results are in close conformity with those of Jones (2007) who found that humic acid increased the number of grains spike because it has the ability to decompose the residues and make nitrogen slowly available to the plant. Similarly, Delfine (2005) also reported significant ($p \leq 0.05$) increase in number of grains per spike by humic acid application. Dileep and Singh (2017) also confirmed that application of K-humate significantly ($p \leq 0.05$) increased the yield and yield components in many cereal crop.

1000-Grain weight

Results indicated that 1000-grain weight was significantly ($p \leq 0.05$) increased by different levels of K-humate application (Table 3). Maximum 1000-grain weight was observed with the application of K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray at 25 days interval after sowing and it was at par with treatments T_1 and T_2 at site-II. Minimum 1000-grain weight of 39.60 g and 37.79 g was recorded at site-I and 2, respectively in plots where no K-humate was applied (T_0). These results are similar to the findings of Delfine et al. (2005) and Khan et al. (2010) who reported that application of humic acid significantly ($p \leq 0.05$) increased 1000-grain weight of wheat. Similar results were reported by Tahir et al. (2017).

Grain yield

Data about grain yield showed that K-humate had significant ($p \leq 0.05$) effect on grain yield of wheat (Table 3). Maximum grain yield of 4675.10 kg ha^{-1} and 4566.50 kg ha^{-1} were recorded at site-1 and site-2, respectively in plots treated with T_3 (K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing). This yield was statistically ($p \leq 0.05$) at par to the grain yield of 4458.90 kg ha^{-1} produced with K-humate @ 25 kg ha^{-1} at sowing + 3 foliar spray at 25 days interval after sowing (T_2) at site-2. Minimum grain yield of 3642.10 and 40.22 kg ha^{-1} from site-I and II were recorded without the application of K-humate (T_0). Humic acid has the ability to release nutrients by decomposing organic matter for longer period of time. Hence, prolonged functioning of green leaves and resultant higher grain yield. Khan et al. (2010) and Bakry et al. (2013) reported an increase in grain yield due to humic acid application. Dileep and Singh (2017) also confirmed that application of K-humate significantly ($p \leq 0.05$) increased the yield and yield components of cereals. Ulukan (2008) also reported similar findings.

Correlation among yield parameters with grain yield of wheat also confirmed the study findings as shown in Figure 1 and 2. The current study results showed that K-humate application to wheat crop @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing caused an increase in the number of grains per spike and 1000-grain weight that ultimately led to improve the grain yield of wheat. A significant improvement in growth parameters of wheat through application of K-humate might have affected the production of assimilates and their

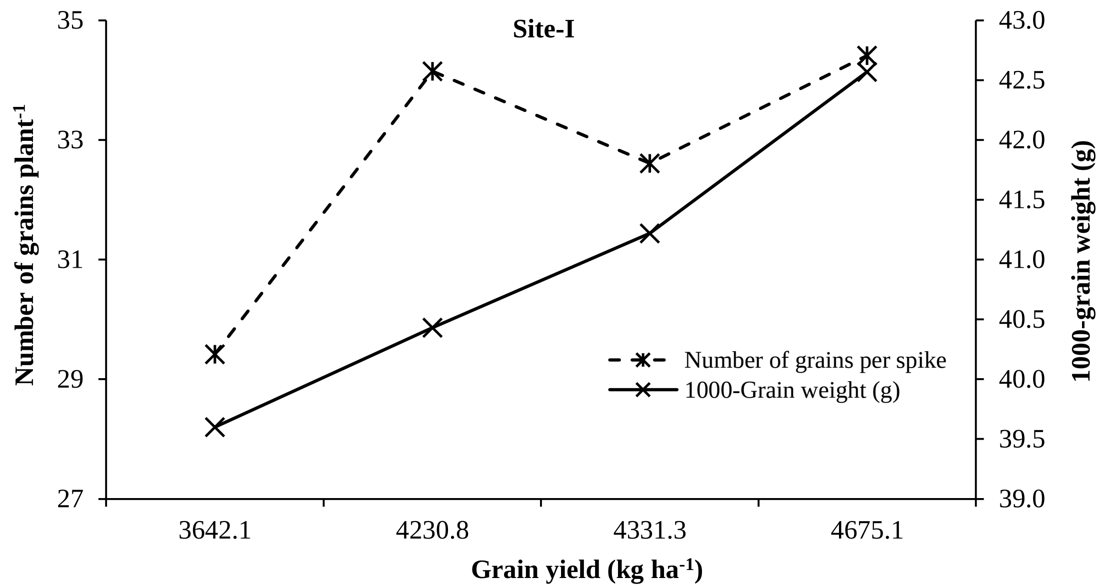

Figure 1 Correlation among number of grain per spike and 1000 grain weight with grain yield of wheat at experimental site-1

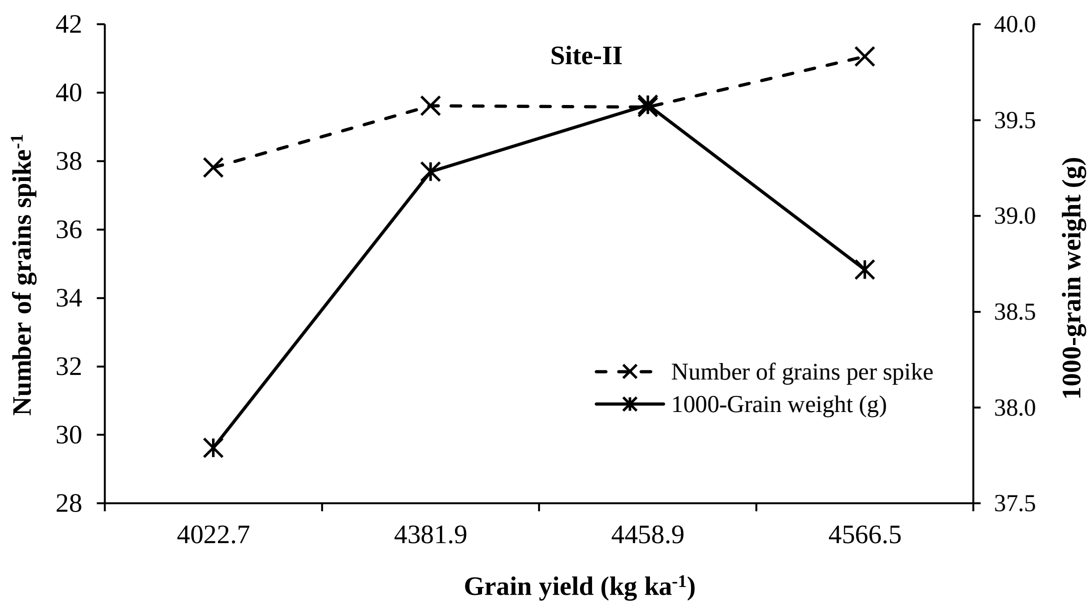

Figure 2 Correlation among number of grain per spike and 1000 grain weight with grain yield of wheat at experimental site-II

translocation to the reproductive organs which resulted in enhanced grain yield. Inamullah and Ali (2014), and Tufail et el. (2014) reported improvement in number of spikelets and grain number per spike in wheat crop, resulting in enhanced wheat productivity. Similar results were reported by Iram et al. (2017).

CONCLUSION

Application of K-humate improved the wheat yield and yield attributes. However, application of K-humate @ 50 kg ha^{-1} at sowing + 3 foliar spray of K-humate at 25 days interval after sowing proved best to improve the wheat productivity under the agro-ecological conditions of Dera Ghazi Khan, Pakistan. It is, therefore, suggested that farming community should apply K-humate @ 50 kg ha^{-1} at sowing + 3 foliar sprays for the improvement of wheat productivity and sustaining soil fertility.

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