Original Research Article

USE OF COAL DERIVED HUMIC ACID AS SOIL CONDITIONER TO IMPROVE SOIL PHYSICAL PROPERTIES AND WHEAT YIELD

ABSTRACT

In Pothwar area of Punjab Pakistan (33 ˚N to 74 ˚E), intensive soil tillage, soil erosion and low crop residue input are the reasons which have led to the deterioration of soil structure. Structurally unstable soils are more susceptible to erosion which, in turn, leads to poor crop productivity. Therefore, a field study was conducted in dry land region of Punjab, Pakistan to improve soil physical health at campus of University Research Farm (PMAS Arid Agriculture University, Rawalpindi). Two different grades (Laboratory and commercial grade) of humic acid along with eight levels were applied for two years. The treatments were HL_0 (control), HL_1 10 kg H.A ha^{-1}, HL_2 20 kg H.A ha^{-1}, HL_3 30 kg H.A ha^{-1}, HL_4 60 kg H.A ha^{-1}, HL_5 90 kg H.A ha^{-1}, HL_6 120 kg H.A ha^{-1}, and HL_7 150 kg H.A ha^{-1} with a basal recommended dose of N-P-K (120-90-60 kg ha^{-1}). Soil parameters such as total organic carbon, saturated hydraulic conductivity, aggregate stability, bulk density, soil water contents and grain yield were recorded. Results showed that humic acid improved the soil physical health in terms of total organic carbon, aggregate stability, saturated hydraulic conductivity, bulk density, total porosity and soil water contents, lab grade humic acid improved physical properties more than commercial grade humic acid. The application of humic acid levels such as HL_6 120 kg H.A ha^{-1}, and HL_7 150 kg H.A ha^{-1} showed significant improvement in wheat grain yield by improving physical properties.

Keywords: *Laboratory grade humic acid, saturated hydraulic conductivity, aggregate stability, Soil organic carbon, wheat production*

INTRODUCTION

Soil fertility problems have been addressed much during the last 50 years, right from the green revolution the major focus was on fertilizer, fertility and enhancing crop growth and yield. Chemical fertilizers are very rich in their nutrient contents and have quick response in crop productivity (Sharif, 1985). In spite of their popularity among the farmers they have unaffordable high costs. Furthermore, readily available nutrients from the applied chemical fertilizers may have some issues like environmental pollution, excessive leaching and fixation in the soil (Freney and Simpson, 1983). The annual consumption of chemical fertilizers in Pakistan is about 5.54 million tones N, 1.24 million tones P and 0.04 million tones K in nutrient forms, it indicates that still a large quantity is needed to be used which requires huge investment per year (Economic survey of Pakistan, 2012-13). Increased inorganic fertilizer usage leads to soil deterioration (Komeili *et al*., 2008). Eroded area is up to 45.12 m ha in 2007 which was 11.1 m ha during 1998 at Pakistan level indicating that 4 times increase only in 10 years due to lack of organic inputs (Manzoor, 2003).

A fertile soil with suitable physical, chemical and biological conditions is prerequisite for higher crop yield, for which several organic and inorganic amendments are applied to increase soil productivity (Cimrin *et al*., 2010). In recent years, there has been increasing interest in amending soils with humic products to increase the productivity of soils (Zheng *et al*., 2006).

Humic acid is the most important fraction of soil organic carbon, and is important factor for maintenance of soil fertility as it is the main constituent of organic fertilizers, through which it supplies nutrients, improve soil aggregation, and stimulate microbial diversity (Carpenter *et al*., 2000; Sathiya *et al*., 2003). Humic acid extracted from different organic sources is mostly utilized in agriculture as a bio-fertilizer and soil conditioner (Nisar and Mir, 1989; Chen *et al*., 2004; Lee *et al*., 2004). The application of humic acid affects differently on physical and chemical properties of soil because of differences in its origin, composition management, and formulations (Lizarazo *et al*., 2005).

Humic acid occurs naturally in lignite deposits and can account up to 10 - 80 % of total lignite contents, and it contains higher contents of moisture, ash, sulfur, and volatile materials depending upon maturity levels of the lignite organic matter (Cavani *et al*., 2003). In Pakistan, the huge reserves of lignitic coal (548 million tones) mainly found in Balochistan (Mach, Duki,), Sindh (Pir Ismail, Khost-Harnai, Dahlol, Meting-Jhumpir, Lakra, Sonda-Thatta, Makarwal) and Punjab (Sor-Range, Salt-Range, Surghar-Range) provinces. In organic matter deficient soils, application of humic substances can serve as soil conditioner which can increase fertilizer retention, stimulate activities of beneficial soil microorganisms, and thus may have positive effects on soil physical properties (Khungar and Manoharan, 2000).

Although there is sufficient literature on the effects of natural humic substances on soil fertility and crop yield (Vallini *et al*., 1996; Pascal *et al*., 2000), but studies regarding the effects of humic substances particularly those on lignitic humic acid on soil properties are limited under rainfed / dry land conditions (Chen *et al*., 2002). The present study was planned with the objectives to observe, (i) the effects of lignite derived humic acid on selected soil physical properties, (ii) the influence of humic acid application on wheat grain yield.

MATERIALS AND METHODS

The impact of humic acid application on soil physical properties and wheat yield was studied through a field experiment conducted at Experimental Farm university area PMAS (Pir Mehr Ali Shah), Arid Agriculture University, Rawalpindi during Rabi season. The experimental soil was sandy clay loam, non saline (EC = 0.31 dS m^{-1}) and non calcareous (pH = 7.7). The soil bulk density and total organic carbon (TOC) contents were 1.4 Mg m^{-3} and 0.6 %, respectively. The levels of two different grades i.e. Laboratory coal derived and commercially coal derived humic acid were 0, 10, 20, 30, 60, 90, 120 and 150 Kg ha^{-1}. The treatments were arranged in RCBD (Randomized Complete Block Design) with three replications. Soil samples were taken before and after harvesting for the analyses of various physical and chemical properties of the soil. Final soil parameters were measured using the following method as, Total Organic Carbon was measured as, organic carbon was oxidized with excess $K_2Cr_2O_7$ through digestion, and the unreacted portion was back titrated (Nelson and Sommers, 1982). Saturated Hydraulic Conductivity was measured by using Guelph permimeter (at 5 cm and 10 cm heads) and infiltration was fitted in Darcy's law (Youngs, 1991). Aggregate Stability was calculated as dry aggregates (1-2 mm) were sieved against water using Yoder-type sieving machine and stable aggregates were oven dried and weighed (Kemper and Koch, 1966). Bulk density was determined by soil cores (98 cm^3) dried at 105 °C were weighed (Bulk density = mass/volume) (Blake and Hartge, 1982). Gravimetric moisture content was measured such as soil water content = water mass/soil mass (Gardner et al., 1991). All data obtained were subjected to statistical analysis using a statistical software (Statix 8.1), and mean values were analysed with LSD test ($P < 0.05$).

Results and Discussion

GRAIN YIELD AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

The results of our study showed that maximum grain yield (3.24 t ha^{-1}) was observed in 90kg ha^{-1} followed by 3.09 t ha^{-1} in 120 kg ha^{-1} level showing 9.86% and 4.51 % more grain yield as compared to control (Table 7). Similarly, the both grades of humic acid were statistically significant with each other and lab grade HA showed 2.97 % more grain yield than commercial grade HA during 2011-12.

Table 7: Grain yield as affected by humic acid levels and grades

Main effects	**Grain Yield (t ha^{-1})**	
Levels	2011-12	2012-13
0	2.95^{d}	3.09^{f}
10	2.96^{d}	3.11^{f}
20	2.96^{d}	3.14^{ef}
30	3.02^{c}	3.20^{de}
60	3.12^{b}	3.27^{cd}
90	3.24^{a}	3.39^{ab}
120	3.09^{b}	3.43^{a}
150	3.07^{b}	3.32^{bc}
Means		
Laboratory grade	3.096^{a}	3.29^{a}
Commercial grade	3.01^{b}	3.20^{b}
Analysis of variance		

	p-value		**p-value**
Levels (L)	<0.05		<0.05
Grades (G)	<0.05		<0.05

Our results exhibited statistically difference in grain yield in the applied humic acid levels as indicated in (Table 7). The maximum yield of grain was observed in 120 kg ha^{-1} level (3.43 t ha^{-1}), followed by 90 kg ha^{-1} (3.39 t ha^{-1}) indicating 11% and 9.71 % enhanced grain yield than control. Both grades of humic acid were statistically significant with each other and lab grade HA showed 2.81 % more grain yield than commercial grade HA during 2012-13.

Humic acid extracted from different organic sources is mostly utilized in agriculture it increases the plant membranes permeability and root respiration rate by higher metabolic activity due to increased nutrient availability and enzymatic activity resulting in higher yield. (Sumukh Das 2001; Chen *et al.*, 2004; Lee *et al.*, 2004). Carpenter *et al.*, (2000) reported that humic acid is the main constituent of organic fertilizers, through which it supplies nutrients, improve soil aggregation, and stimulate microbial diversity and activity and thus increases the yield.

TOTAL ORGANIC CARBON AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

The application of humic acid at 150 Kg ha^{-1} level showed highest total organic carbon (8.17 g kg^{-1}) followed by 8.0g kg^{-1} in 120 Kg ha^{-1} with 35.04% and 32.23% increase over control (Table 1). Likewise, in the second experimental year maximum total organic carbon (8.79 g kg^{-1}) was observed in150 Kg ha^{-1} followed by 8.69 g kg^{-1} in 120 Kg ha^{-1} showing 47.23% and 45.56 % more total organic carbon as compared to control. On the other hand, lab grade humic acid was significantly higher as compared to commercial grade in both years. As humic acid is mostly carbon in nature (Kulikova *et al.,* 2005) so it helped to improve the soil organic carbon status. YE *et al.*, (2010) found increase in organic carbon contents of soil due to humic acid addition. Moreover, it prevents carbon from decomposition or mineralization due to refractory nature of its chemical structure which makes it resistant against microbial attack.

Table 1: Total soil organic carbon as affected by humic acid levels and grades

	2011-12			2012-13		
Levels (kg ha^{-1})	**Lab. Grade**	**Comm. Grade**	**Means**	**Lab. Grade**	**Comm. grade**	**Means**
0	6.13	6.04	6.05^{d}	5.95	6.00	5.97^{e}
10	6.72	6.39	6.55^{cd}	6.76	6.43	6.59^{d}
20	6.53	6.47	6.50^{cd}	6.80	6.38	6.59^{d}
30	7.30	6.82	7.06^{bc}	7.30	5.98	6.64^{d}
60	7.73	7.16	7.44^{ab}	7.82	6.74	7.28^{c}
90	7.97	7.08	7.52^{ab}	8.51	7.62	8.06^{b}
120	8.27	7.73	8.00^{a}	9.66	7.92	8.69^{a}
150	8.59	7.75	8.17^{a}	9.42	7.97	8.79^{a}
Means	7.40	6.93		7.78	6.88	

AGGREGATE STABILITY AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

The results of our study showed that aggregate stability was statistically different in all applied humic acid levels and highest aggregate stability was recorded in 150 Kg ha^{-1} level (27.12 %) followed by 120 Kg ha^{-1} (24.0 %) and in 90 Kg ha^{-1} (21.32%) and the lowest aggregate stability was observed in control (17.55 %) indicating 54.8 %, 37.2 % and 21.7 % higher aggregate stability in 150 Kg ha^{-1}, 120 Kg ha^{-1} and 90 Kg ha^{-1} respectively as compared to control (Table 2). Both grades of humic acid were found to be statistically significant highlighting 5.8 % higher aggregate stability in lab grade as compared to commercial grade during first year of study.

During second year of study highest aggregate stability (31.58 %) was recorded in 150 kg ha^{-1} followed by 30.66 % in 120 kg ha^{-1} and 27.59 % in 90 kg ha^{-1} and lowest aggregate stability was observed in control (18.97 %) indicating 66.47 %, 61.62 % and 45.44% higher aggregate stability in 150, 120 and 90 kg ha^{-1}, respectively as compared to control. In the same way, both grades of humic acid were found to be statistically significant highlighting 6.83 % higher aggregate stability in lab grade as compared to commercial grade.

The development of soil structure can always be judged by the status of stability of soil aggregates (Six *et al.,* 2000). Aggregate stability and soil organic carbon content is greatly interlinked, because it is observed that lower stability also lowers the levels of soil organic carbon which in turn affects the plant growth and development. Amendments from organic source increase the total organic carbon in soil (Melero *et al.*, 2007).Treatments, where high amount of aggregate stability was observed due to humic acid, also showed higher values of soil organic carbon. A strong positive correlation (r = 0.62) was found between aggregate stability and total organic carbon (Table 3). Polyvalent cations complexation within surface of clay and humic acid-oxygen-containing groups surrounds the hydrophobic constituents all around the soil aggregate (Mbagwu, 2003). Such type of hydrophobic coating decrease the soil slaking in water, hence help in maintaining the aggregate stability and prevent the loss of soil by run-off. It is reported that humic acid is the most important fraction of soil organic matter, and is important factor for maintenance of soil through which it improves soil aggregation (Carpenter *et al.*, 2000; Sathiya *et al.*, 2003). Addition of a mixture of fulvic and humic acids in soil can significantly increase the soil aggregation (Barzegar *et al.* 2002). Humic acid extracted from different organic sources is mostly utilized in agriculture as a bio-fertilizer and soil conditioner (Nisar and Mir, 1989; Chen *et al.*, 2004; Lee *et al.*, 2004) and thus have positive effect on soil physical properties.

Table 3: Soil aggregate stability as affected by humic acid levels and grades

	2011-12			**2012-13**		
Levels (kg ha^{-1})	**Lab. Grade**	**Comm. Grade**	**Means**	**Lab. Grade**	**Comm. grade**	**Means**
0	17.55	17.46	17.51^{e}	18.81	19.13	18.97^{d}
10	17.64	17.32	17.48^{e}	20.17	20.04	20.10^{d}
20	18.77	17.49	18.13^{de}	21.07	19.87	20.47^{d}
30	18.43	17.57	18.00^{de}	21.72	19.22	20.47^{d}
60	20.39	19.03	19.71^{cd}	24.77	22.85	23.81^{c}
90	21.92	20.72	21.32^{c}	28.61	26.58	27.59^{b}
120	24.65	23.44	24.04^{b}	31.78	29.53	30.66^{a}
150	28.40	25.83	27.12^{a}	33.16	30.01	31.58^{a}
Means	20.97	19.82		25.01	23.41	

Table **2:** Correlation among different soil parameters

		Bulk Density	**Grain Yield**	**Saturated Hydraulic Conductivity**	**Total Organic Carbon**	**Aggregate Stability**
Saturated Hydraulic Conductivity	**R**	-0.4190	0.5924			
	P Value	0.0001	0.0001			
Total organic carbon	**R**	-0.5143	0.6025	0.8293		
	P Value	0.0001	0.0001	0.0001		
Aggregate Stability	**R**	-0.4066	0.3514	0.6148	0.6247	
	P Value	0.0001	0.0001	0.0001	0.0001	
Water content	**R**	0.3633	0.3191	0.4979	0.5342	0.5126
	P Value	0.0001	0.0001	0.0001	0.0001	0.0001

SATURATED HYDRAULIC CONDUCTIVITY AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

In first experimental year, the saturated hydraulic conductivity was 65.96 mm hr^{-1} in 150 kg ha^{-1} followed by 66.67 mm hr^{-1} in 120 kg ha^{-1} indicating 89.37 % and 91.41 % more saturated hydraulic conductivity as compared to control (Table 4). Minimum saturated hydraulic conductivity was observed in 10 kg ha^{-1} (30.94 mm hr^{-1}) level application. Overall Lab. grade humic acid showed significantly high hydraulic conductivities than commercial grade.

The saturated hydraulic conductivity was maximum (55.1 mm hr^{-1}) in 120 kg ha^{-1} followed by 53.14 mm hr^{-1} in 90 kg ha^{-1} indicating 25.76 % and 21.26 % more saturated hydraulic conductivity as compared to control. Minimum saturated hydraulic conductivity was observed in 20 kg ha^{-1} (42.5 mm hr^{-1}) during second experimental year.

Table 4: Saturated hydraulic conductivity as affected by humic acid levels and grades

	2011-12			2012-13		
Levels (kg ha^{-1})	**Lab. Grade**	**Commercial grade**	**Means**	**Lab. Grade**	**Commercial grade**	**Means**
0	35.05	34.61	34.83^{d}	43.16	44.48	43.82^{b}
10	35.23	26.65	30.94^{d}	44.73	48.16	46.44^{b}
20	34.73	34.74	34.73^{d}	45.34	44.34	44.84^{b}
30	37.90	36.24	37.07^{cd}	45.78	39.23	42.50^{b}
60	47.81	38.53	43.17^{bc}	40.48	49.00	44.74^{b}
90	51.00	44.39	47.70^{b}	58.50	47.78	53.14^{a}
120	70.81	62.53	66.67^{a}	57.72	52.50	55.11^{a}
150	73.10	58.82	65.96^{a}	53.23	50.87	52.05^{a}
Means	48.20	42.06		48.61	47.04	

The improvement in total organic carbon of soil and aggregate stability improved the saturated hydraulic conductivity of soil. With the improvement in organic carbon of the soil and the aggregate stability at higher applied levels of humic acid, the higher rate of saturated hydraulic conductivity was also observed. The positive correlations of organic carbon (r = 0.82) and aggregate stability (r = 0.61) with saturated hydraulic conductivity which indicate that the improvement in saturated hydraulic conductivity is mainly due the aggregate stability and soil organic carbon (Table 2).

BULK DENSITY AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

The highest bulk density (1.61 Mg m^{-3}) was found in HL-0 followed by 1.57 Mg m^{-3} in 10 kg ha^{-1} level and lowest bulk density was observed in 150 kg ha^{-1} level (1.46 Mg m^{-3}) with a decline of about 9.31 %, followed by 1.48 Mg m^{-3} in 120 kg ha^{-1} level with 8.0% less bulk density as compared to control in 2011-12 (Table 5). Further, the both grades of humic acid were statistically non significant with each other.

While, in second experimental year (2012-13), the results highlighted that maximum bulk density was observed in control (1.53 Mg m^{-3}) and minimum bulk density was observed in 150kg ha^{-1} level (1.38 Mg m^{-3}) which showed 9.8 % decrease in bulk density, followed by 1.42 Mg m^{-3} with 7.18 % less bulk density in 120 kg ha^{-1} as compared to control during 2012-13. Moreover, the grades of humic acid were statistically non significant with each other.

Table 5: Bulk density as affected by humic acid levels and grades

	2011-12			2012-13		
Levels (kg ha^{-1})	**Lab. Grade**	**Comm. grade**	**Means**	**Lab. Grade**	**Comm. Grade**	**Means**
0	1.60	1.62	1.61^{a}	1.53	1.54	1.53^{a}
10	1.57	1.58	1.57^{ab}	1.54	1.53	1.53^{a}
20	1.61	1.56	1.56^{ab}	1.51	1.54	1.53^{a}
30	1.55	1.56	1.55^{ab}	1.52	1.54	1.53^{a}
60	1.54	1.55	1.55^{ab}	1.49	1.53	1.51^{a}
90	1.52	1.53	1.53^{ab}	1.42	1.49	1.45^{ab}
120	1.48	1.49	1.48^{b}	1.44	1.41	1.42^{b}
150	1.45	1.48	1.46^{b}	1.36	1.41	1.38^{b}
Means	1.55	1.54		1.50	1.47	

The Pearson correlation r value indicates that the bulk density has a significant and negative correlation with aggregate stability and soil organic carbon (Table 2). This describes that the decrease in bulk density is mainly due to the improvement in organic carbon and soil aggregate stability. The use of humic acid in soil as an organic source improved the physical condition of soil by improving the aggregate stability of soil and reducing the compactness of soil which resulted in decrease in bulk density of soil and finally improved the water infiltration (Barzegar *et al.*, 2002; Zeleke *et al.*, 2004). Bresson et al., (2001) have proved significant and linear relationship between bulk density reduction and increase in organic carbon of the soil due to the application of humic acid.

GRAVIMETRIC WATER CONTENT AS AFFECTED BY HUMIC ACID GRADES AND LEVELS

The data regarding the effect of humic acid on gravimetric water contents in 2011-12, revealed that maximum gravimetric water contents (6.10 %) observed in 150 kg ha^{-1}, followed by 120 and 90 kg ha^{-1} application, respectively as compared to control (Table 6) during first experimental year.

The data regarding the effect of humic acid on gravimetric water contents revealed maximum gravimetric water contents (6.49 %) observed in 150 kg ha^{-1} application, followed by 6.42 g kg^{-1} in 120 kg ha^{-1} level and 5.65 g kg^{-1}in 90 kg ha^{-1} level and minimum gravimetric water contents (3.83 g kg^{-1}) in control indicating 69%, 67.6% and 47.5 more gravimetric water contents in 150, 120 and 90 kg ha^{-1}, respectively as compared to control in 2012-13.

Also, both grades of humic acids exhibited statistically significant difference. More gravimetric water contents were recorded in lab grade as compared to commercial grade in both experimental years.

Gravimetric water contents were well correlated with aggregate stability, soil organic carbon and bulk density of soil with the pearson correlation coefficient values of 0.51, 0.53 and 0.36, respectively. YE *et al.* (2010) while seeing the effect of humic acid on the physical properties of soil in tobacco field area observed increase in the ability of soil to maintain water due to decrease in soil bulk density and increase in the porosity. Various researchers reported that the humic acid application improved the water holding capacity of soil (Mylonas & McCants, 1980; Majathoud, 2004).

Table 6: Gravimetric water contents as affected by humic acid levels and grades

	2011-12			2012-13		
Levels (kg ha^{-1})	**Lab. Grade**	**Comm. grade**	**Means**	**Lab. Grade**	**Comm. Grade**	**Means**
0	3.72	3.75	3.73^{d}	3.84	3.83	3.83^{e}
10	4.26	4.13	4.19^{cd}	4.63	4.50	4.57^{de}
20	4.95	4.56	4.75^{bc}	4.87	4.77	4.82^{cd}
30	4.63	4.77	4.70^{bc}	5.53	4.70	5.11^{cd}
60	5.12	5.08	5.10^{b}	5.67	5.39	5.53^{bc}
90	5.24	5.09	5.17^{b}	5.86	5.44	5.65^{abc}
120	6.61	5.64	6.12^{a}	6.98	5.87	6.42^{ab}
150	6.27	5.93	6.10^{a}	7.07	5.91	6.49^{a}
Means	5.10	4.87		5.56	5.05	

CONCLUSION

The study revealed that humic acid enhances the soil health by improving total organic carbon, aggregate stability, bulk density and saturated hydraulic conductivity. Humic acid also substantially improves wheat yield by improving soil health. Laboratory grade humic acid performs better than commercial grade humic acid in improving wheat production and soil health. This study gives light to the recommendation of humic acid for the improvement of soil physical conditions and crop yield in future by the scientific community.

Laboratory grade humic acid improved physical properties more than by commercial grade humic acid for the wheat production and soil health improvement during both the years. Differences among applied levels of both grades of humic acid were statistically significant than control. Most of the parameters showed similar results at 120 and 150 kg ha^{-1} levels of humic acid, so 120 kg ha^{-1} dose rate is an economical level of humic acid as compared to 150 kg ha^{-1} level.

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