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 has led to 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 two different sites viz., Experimental Farm at the main campus of University Research Farm. 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 total porosity, 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. Differences among applied levels of both grades of humic acid were statistically significant than control.

Keywords: *Humic acid, physical properties, aggregate stability, wheat yield*

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 strong 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 matter, 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 and can account for 10 to 80 percent of total lignite contents, high moisture, ash, sulfur, and volatile matter depending upon maturity level of the lignite organic matter (Villa *et al*., 1992; Cavani *et al*., 2003). Some of 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 of Pakistan. In organic matter deficient soils, application of humic substances can add organic matter, 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 to utilize the indigenous coal derived humic acid and to observe its effects on soil physical properties and on wheat crop production. The objectives were (i) Effect of lignite derived humic acid on selected soil physical properties, (ii) 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 two different sites viz., Experimental Farm university area and Koont Research Farm PMAS, Arid Agriculture University, Rawalpindi during Rabi season. 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 with three replications. Soil samples were taken randomly before and after harvesting for the analyses of various physical and chemical properties of the soil. 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. This analysis was performed using a statistical software (Statix 8.1), and mean values were grouped with LSD multiple range test ($P < 0.05$).

Results and Discussion

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 8.0 kg ha^{-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 of humic acid was significantly higher as compared to commercial grade in both years.

The interaction of humic acid levels and grades exhibited 40.13 %, 34.91% and 30.0 % increase in total organic carbon due to 150 Kg ha^{-1}, 120 Kg ha^{-1} and 90 Kg ha^{-1} of lab grade, respectively in contrast to control. Similarly, in second year the interactive effect of humic acid levels and grades showed 58.31 %, 62.35% and 43.02 % increase in total organic carbon by 150 Kg ha^{-1}, 120 Kg ha^{-1} and 90 Kg ha^{-1}of lab grade, respectively in contrast to control.

Correlation coefficient (r) values among different soil variables (Table 2) shows the degree of interrelation ship of various variables between each other. Treatments, where high amount of aggregate stability was observed due to humic acid contained high values of organic carbon. This indicates that with the improvements in total soil organic carbon the aggregate stability was also improved by the application of humic acid. A strong positive correlation was found between aggregate stability and total organic carbon (r=0.6247).

Eynard *et al.,* (2004) reported a rapid decrease in the quantity of stable aggregates and soil organic carbon due to continuous cultivation. 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).

Six *et al.,* (2000) also reported that the development of soil structure can always be judged by the status of stability of soil aggregates. Chefetz *et al.,* (2000) found that with the improvements in soil aggregate resulted in increase in soil organic carbon due to presence of partially decomposed material within the macroaggregates. 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. YE *et al*., (2010) found increase in organic matter contents of soil due to humic acid addition. Humic acid increases the soil organic matter as it consists of 50-90 % organic matter (Kulikova *et al.,* 2005) moreover it prevents carbon due to its 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	6.13fg	6.04g	6.05d	5.95f	6.00f	5.97e
10	6.72defg	6.39efg	6.55cd	6.76de	6.43ef	6.59d
20	6.53efg	6.47efg	6.50cd	6.80de	6.38ef	6.59d
30	7.30bcde	6.82defg	7.06bc	7.30cd	5.98f	6.64d
60	7.73abcd	7.16cdef	7.44ab	7.82bc	6.74de	7.28c
90	7.97abc	7.08cdefg	7.52 ab	8.51b	7.62c	8.06b
120	8.27ab	7.73abcd	8.00a	9.66a	7.92bc	8.69a
150	8.59a	7.75abcd	8.17a	9.42a	7.97bc	8.79a
Means	7.40a	6.93b		7.78a	6.88b	

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	0.0000	0.0000			
Total organic carbon	**R**	-0.5143	0.6025	0.8293		
	P Value	0.0000	0.0000	0.0000		
Aggregate Stability	**R**	-0.4066	0.3514	0.6148	0.6247	
	P Value	0.0000	0.0000	0.0000	0.0000	
Water content	**R**	0.3633	0.3191	0.4979	0.5342	0.5126
	P Value	0.0000	0.0000	0.0000	0.0000	0.0000

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} (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 3). In the same way, 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.

The interaction of humic acid levels and grades exhibited 62 %, 40.4 % and 24.9 % enhancement in aggregate stability due to lab grade applied at 120 Kg ha^{-1}, 90 Kg ha^{-1} and 60 Kg ha^{-1}, respectively in contrast to control. Similar trends were also observed in the second experimental year. In 2012-13, the results showed that aggregate stability was statistically different in all applied humic acid levels showing the order of 150 > 120 > 90 > 60 > 30 > 20 > 10 > 0 kg ha^{-1} humic acid. Highest aggregate stability (31.58 %) was recorded in 150 kg ha^{-1} followed by 30.66 g kg^{-1} in 120 kg ha^{-1} and 27.59 g kg^{-1} 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 humic acid levels and grades interaction effect exhibited 76.29 %, 68.95 % and 52.47 % enhancement in aggregate stability due to the application of 150, 120 and 90 kg ha^{-1}by lab grade, respectively in contrast to control. While, about 57.12 %, 54.61 % and 38.74 % augmentation in aggregate stability was noticed in 150, 120 and 90 kg ha^{-1}, respectively due to commercial grade humic acid in comparison to control.

The increasing level of soil organic carbon increased the soil aggregate stability. As it is well correlated (r = 0.62) with the soil organic carbon. A positive significant correlation among soil aggregate stability and organic carbon was observed (Table 2). A positive correlation was found between soil organic carbon and soil aggregate stability (Six *et al.*, 2000). 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, and stimulate microbial diversity (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 (Khungar and Manoharan., 2000).

Table 3: Soil aggregate stability as affected by different levels of humic acid

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

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 % and91.41 % 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 interactive effect of humic acid levels and grades showed 108 %, 103 % and 47 % increase in saturated hydraulic conductivity by the application of lab grade at the rates of 150, 120 and 90 kg ha^{-1}, respectively in contrast to control. Whereas, 69.95 % and 80.67 % increase in saturated hydraulic conductivity was found in commercial grade applied at150 kg ha^{-1} and 120 kg ha^{-1}levels, respectively, as compared to control.

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}).

The interactive effect of humic acid levels and grades showed 35.54%, 33.73 % and 23.33 % increase in saturated hydraulic conductivity in 90,120 and 150 kg ha^{-1}, respectively in contrast to control in lab grade. Whereas, 18.03 % and 14.36 % increase in saturated hydraulic conductivity was found in 120 and 150 kg ha^{-1}, respectively by the application of commercial grade HA in comparison to control 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	35.05gh	34.61gh	34.83d	43.16def	44.48def	43.82b
10	35.23gh	26.65h	30.94d	44.73cdef	48.16bcd	46.44b
20	34.73gh	34.74gh	34.73d	45.34cdef	44.34def	44.84b
30	37.90fg	36.24gh	37.07cd	45.78cde	39.23f	42.50b
60	47.81ef	38.53fg	43.17bc	40.48ef	49.00bcd	44.74b
90	51.00de	44.39efg	47.70b	58.50a	47.78bcd	53.14a
120	70.81ab	62.53bc	66.67a	57.72a	52.50ab	55.11 a
150	73.10a	58.82cd	65.96a	53.23ab	50.87bc	52.05a
Means	48.20a	42.06b		48.61a	47.04a	

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. A positive correlation was found between organic carbon, aggregate stability of soil and saturated hydraulic conductivity which indicate that the improvement in saturated hydraulic conductivity is mainly due the aggregate stability and soil organic carbon. The correlation r value is given in 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 g kg^{-1} in control 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} with 8.0% less bulk density in 120 kg ha^{-1} as compared to control in 2011-12 (Table 5). Further, the both grades of humic acid were statistically non significant with each other. The interactive effect of humic acid levels and grades showed 9.37 % decrease in bulk density by 150 kg ha^{-1} level in contrast to control in lab grade. Whereas, 8.64 % and 8.02 % decrease in bulk density was found in 150 and 120 kg ha^{-1} levels, respectively by the application of commercial grade HA in comparison to control during first experimental year.

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 Humic acid ha^{-1} (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	1.60a	1.62a	1.61a	1.53ab	1.54a	1.53a
10	1.57a	1.58a	1.57ab	1.54a	1.53ab	1.53a
20	1.61a	1.56a	1.56ab	1.51abc	1.54a	1.53a
30	1.55a	1.56a	1.55ab	1.52abc	1.54a	1.53a
60	1.54a	1.55a	1.55ab	1.49abc	1.53a	1.51a
90	1.52a	1.53a	1.53ab	1.42bcd	1.49abc	1.45ab
120	1.48a	1.49a	1.48b	1.44abcd	1.41cd	1.42b
150	1.45a	1.48a	1.46b	1.36d	1.41cd	1.38b
Means	1.55a	1.54a		1.50a	1.47a	

The humic acid levels and grades interaction showed 11.1 % and 7.18 % decrease in bulk density in 150 and 90 kg ha^{-1}, respectively in contrast to control in lab grade. Whereas, 8.44 % and 2.61 % decrease in bulk density was found in 150 and 90 kg ha^{-1}, respectively by commercial grade HA in comparison to control during 2012-13.

The Pearson correlation r value indicates that the bulk density has a significant and positive correlation with aggregate stability and soil organic carbon (Table 2). Which 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).

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).

The interaction of humic acid levels and grades showed 68.5%, 77.6% and 45.6% increase in gravimetric water contents by the application of lab grade humic acid with 150, 120 and 90 $kgha^{-1}$, respectively in contrast to control. Whereas, 58.0%, 50.0% and 35.7% increase in water was found in 150, 120 and 90 kg ha^{-1}, respectively by commercial grade HA than control 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 2011-12.

The interaction of humic acid levels and grades showed 84%, 81.7% and 52.6% increase in gravimetric water contents by 150, 120 and 90 kg ha^{-1} levels application, respectively in contrast to control in lab grade. Whereas, 54.0%, 53.2% and 42% increase in water was found in 150, 120 and 90 kg ha^{-1} levels, respectively by commercial grade HA than control during 2012-13.

Also, both of the grades of humic acids exhibited statistically significant difference and more gravimetric water contents were recorded in lab grade than commercial grade in both experimental years.

Gravimetric water contents were well correlated with aggregate stability, soil organic carbon, bulk density of soil and total porosity. The r values of pearson correlation are given in Table 2. 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 (Vaughan & Linehan, 1976; 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	3.72g	3.75g	3.73d	3.84d	3.83d	3.83e
10	4.26e-g	4.13fg	4.19cd	4.63bcd	4.50cd	4.57de
20	4.95cd-f	4.56d-g	4.75bc	4.87bcd	4.77bcd	4.82cd
30	4.63d-g	4.77d-g	4.70bc	5.53bc	4.70bcd	5.11cd
60	5.12c-f	5.08cd-f	5.10b	5.67bc	5.39bc	5.53bc
90	5.24b-e	5.09 c-f	5.17b	5.86ab	5.44bc	5.65abc
120	6.61a	5.64a-d	6.12a	6.98a	5.87ab	6.42ab
150	6.27ab	5.93a-c	6.10a	7.07a	5.91ab	6.49a
Means	5.10a	4.87a		5.56a	5.05b	

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} 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.

The interactive effect of humic acid levels and grades showed 12.50%, 6.98 % and 6.53% increase in grain yield by 90, 120 and 150 kg ha^{-1} respectively in contrast to control in lab grade (Figure 1). Whereas, 7.23%, 2.03 % and 1.69 % increase in grain yield was found in 90, 120 and 150 kg ha^{-1}, respectively by the application of commercial grade HA in comparison to control during 2011-12.

Table 7: Grain yield as affected by humic acid levels and grades at university campus research farm site

Main effects	**Grain Yield (t ha^{-1})**	
Levels	2011-12	2012-13
0	2.95d	3.09f
10	2.96d	3.11f

20	2.96d	3.14ef
30	3.02c	3.20de
60	3.12b	3.27cd
90	3.24a	3.39ab
120	3.09b	3.43a
150	3.07b	3.32bc
Means		
Laboratory grade	3.096a	3.29a
Commercial grade	3.01b	3.20b
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} (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.

The results of interaction of humic acid levels and grades exhibited 14.56%, 13.27 % and 9.06% boost up in grain yield by 90, 120 and 150 kg ha^{-1}, respectively in contrast to control in lab grade (Figure 1). Whereas, 7.71%, 6.15 % and 5.82 % increase in grain yield was found in 90, 120 and 150 kg ha^{-1}, respectively by the application of commercial grade HA in comparison to control during 2012-13.

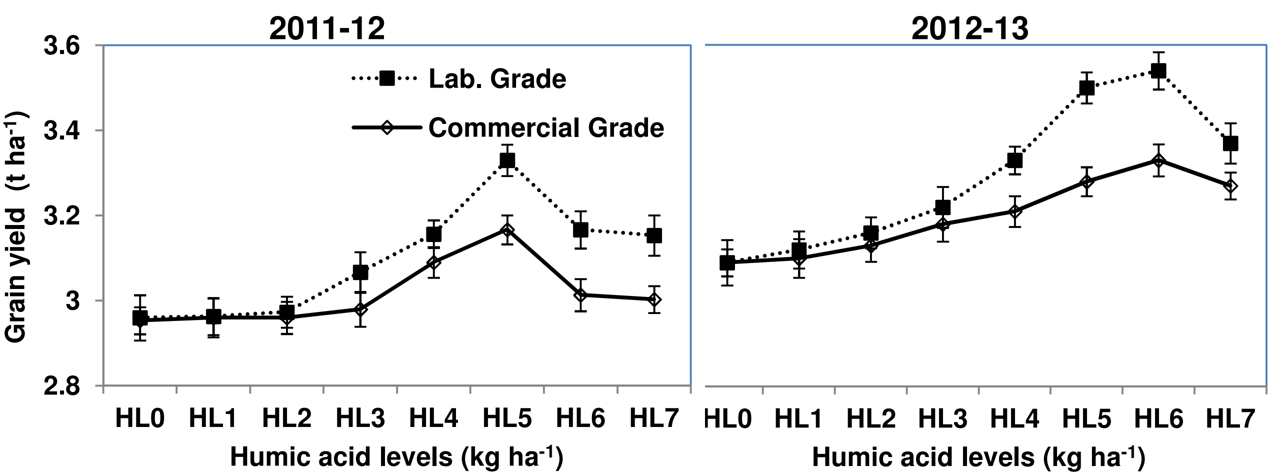

Figure 1: Grain yield as affected by humic acid levels and grades in both years

HL0 = 0 Kg H.A ha^{-1}, HL1 = 10 Kg H.A ha^{-1}, HL2 = 20 Kg H.A ha^{-1}, HL3 = 30 Kg H.A ha^{-1},
HL4 = 60 Kg H.A ha^{-1}, HL5 = 90 Kg H.A ha^{-1}, HL6 = 120 Kg H.A ha^{-1}, HL7 = 150 Kg H.A ha^{-1}
With a basal recommended dose of N.P.K 120 90 60 kg ha^{-1}

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. (Nisar and Mir, 1989; 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.

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