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Improvement of soil properties, nutrient availability and wheat traits induced by the addition of organic materials: A field study

Awad M.*, El-Sayed M. M.

Department of Soils and Water, Faculty of Agriculture, Al-Azhar University, Assiut 71524, Egypt

Abstract

Recently, intensive farming systems entailing abundant use of chemical fertilizers have deteriorated agricultural soils and contributed to environment pollution which necessitates testing organic amendments. The objectives of the present multi-year study were to investigate the impact of different soil organic amendments *i.e*. humic acid (HA) and molasses (Ms) applied at 0.25 and 0.50% (v/w) on soil properties and to find out optimum application level for maximizing growth and yield of wheat. The results showed that soil bulk density (BD) and total porosity were significantly improved with the application of Ms applied at 0.50% as compared to HA application. In both growing seasons, the relative change in field capacity (FC) and wilting point (WP) due to the application of Ms in the surface layer at 0.50% were increased by 14% and 33.13, respectively over the control. The corresponding values of HA were 25.40 and 27.84%, respectively than the control. The increase in nitrogen availability was more pronounced with the application of Ms than HA application, while the opposite was true for available phosphorus (P) and potassium (K). The maximum plant height was observed with a lower rate of HA, which was 16.59% more than the control. The application of Ms at higher rate was superior in increasing the grain and straw yield which were 35.39 and 113.01%, respectively more than the control treatment. The grain N, P, and K contents were increased by 19.13, 69.57, and 56.98% with the application of a higher rate of HA. Thus, it is concluded that the application of organic amendments hold potential to improve physicochemical and hydrological properties of soil which ultimately trigger growth, yield, and nutrient accumulation in wheat.

Keywords: organic amendment, humic acid, molasses, wheat, physicochemical properties, nutrient availability.

*Corresponding author: Awad M.,
E-mail address: mahrousawad.4419@azhar.edu.eg

1. Introduction

Globally, ensuring food security of the skyrocketing population has emerged as one of the main challenges posed to modern farming systems under changing climate scenario. The modern intensive farming systems have seriously deteriorated agricultural soils along with causing environmental pollution (Abo-Baker, 2017; Tadesse *et al*., 2013; Turky *et al*., 2020). Wheat (*Triticum aestivum* L.) is being cultivated on all habitat-able continents of the world and fulfills dietary requirement of over half of world population (Samavat and Samavat 2014; Schenck, 2001; Pyakurel *et al*., 2019). It is considered one of the major cereal crops in the world in terms of total area under cultivation and production. It provides almost 20% of food calories for people in the world, and it is the most important food crop in Egypt. Higher production of wheat is the ultimate goal to meet the growing demand for food by the increasing population (Schenck, 2001). Wheat is among the crops of which yield is severely affected under nutrient-deficient soils *i.e*., sandy soils. Therefore, sustainable agriculture in these areas depends on adding organic amendments to meet the requirements of soil fertility and increase the yield. To meet the high wheat production, farmers resort to increasing mineral fertilization, especially macronutrients, as a result of nutrient depletion from the soil by intensive agriculture. This imbalanced use of chemical fertilizers deteriorates the physicochemical, and biological properties of soil and its health (Pyakurel *et al*., 2019). In Egypt, the land area under plough is decreasing rapidly and intensive wheat farming has led to serious decline in soils fertility status. The use of chemical fertilizers in abundant quantities for achieving higher crops yield has contributed significantly to global warming through gaseous emissions from agricultural fields (Awad *et al*., 2007). On other side, increasing prices of chemical fertilizers have led to their sub-optimal use in developing countries of Asia and Africa which has compromised the nutritional security of millions of people (Awad, 2016). Recently, organic amendments potential for improving soil physico-chemical characteristics and boosting wheat yield has been explored (Melero *et al*., 2007). Different organic manures have been reported to improve soil structure, nutrients availability and exchange, maintain soil health, and increase nutrient use efficiency. In addition to its effect on nutrient contents, these organic amendments improve water holding capacity by increasing porosity, which leads to improved plant growth, especially in newly cultivated soils. In general, these soils are characterized by a lack of nutrients (especially micronutrients), very low in organic matter, high alkalinity (high pH), poor physical properties, and low moisture contents (Ahmad *et al*., 2018; Awad *et al*., 2007; Jamal *et al*., 2018; Melero *et al*., 2007; Samavat and Samavat, 2014). Among organic amendments, molasses which is a by-product of the sugarcane industry contains various nutrients and may serve as a carbon and micronutrients source. Its application in optimum quantities may boost fertility status of the soils. It was also reported that molasses application remained effective in improving the nutrient absorption efficiency and nitrogen fixation through its growth promoting effect on rhizobacteria (Samavat and Samavat, 2014). To the best of our knowledge, there are conflicting findings pertaining to the use of molasses and fresh studies are needed to harmonize the results regarding beneficial effects of molasses on soil structure, nutrients availability and wheat yield. In addition, humic acid (HA) which is a main fraction of humic substances, soil carbon and composted organic matter. The HA application significantly improved nutrient availability, enhanced soil physicochemical characteristics, and bacterial population in the rhizosphere (Awad, 2016; Awad *et al*., 2007). Furthermore, HA reduced soil pH which led to higher nutrients availability (Li *et al*., 2019). In alkaline calcareous sandy loam soils, wheat grain yield was increased by 11-21% over control as a result of HA application derived from plant and coal materials (Khan *et al*., 2018). However, there exist a considerable research gap regarding the effects of HA with other organic manures such as molasses which requisite conducting further studies. Thus, it was hypothesized that molasses and humic acid might prove effective in ameliorating the soil for boosting wheat yield. The current research aimed to investigate the impact of different soil organic amendments for optimizing the level of their application in order to ameliorate soil properties and nutrients availability along with boosting the growth and productivity of wheat.

2. Materials and methods

2.1 Experimental site and treatments description

The field experiments were carried out at the experimental farm of Al-Sheikh Allam Al-Monshaah, Sohag governorate, Egypt (26°52- 41= N latitude and 31°75- 96= E longitude) during two successive growing seasons of 2017-18 and 2018-19. The weather data (temperature, wind speed, solar radiations, and relative humidity) recorded during both seasons are presented in Table (1). Before the conduction of the field experiment, the soil was analyzed regarding various physicochemical properties (Table 2).

Table (1): Weather data recorded during the study period.

Date	Temperature (°C)			Wind speed (m s^{-1})	Solar radiations (MJ m^{-2} day^{-1})	Relative humidity (%)
	Maximum	Minimum	Average			
2017-2018						
November 2017	28.80	14.50	21.60	2.40	13.00	57.00
December 2017	21.70	7.90	14.80	2.50	14.00	60.00
January 2018	20.04	5.37	12.70	2.50	16.32	61.00
February 2018	26.49	11.24	18.87	2.70	18.91	54.00
March 2018	31.55	14.33	22.94	3.20	23.24	43.00
April 2018	32.98	15.89	24.43	3.60	25.04	37.00
May 2018	38.10	22.14	30.12	3.50	26.64	35.00
2018-2019						
November 2017	26.60	13.00	19.80	2.30	13.00	54.00
December 2017	20.30	7.10	13.70	2.50	15.00	65.00
January 2018	18.80	5.00	11.90	2.10	15.00	60.00
February 2018	21.50	7.10	14.30	2.60	18.00	48.00
March 2018	25.10	9.10	17.10	2.90	23.00	35.00
April 2018	30.10	13.80	21.90	3.20	24.00	34.00
May 2018	38.40	20.80	29.60	3.00	27.00	30.00

Table (2): Physicochemical properties of the soil collected from the experimental area.

Properties	Units	2017-2018		2018-2019	
		Soil depth (cm)		Soil depth (cm)	
		0-30	30-60	0-30	30-60
Soil texture	---	Sandy	Sandy	Sandy	Sandy
Saturation percent (SP)	%	29.00	30.00	29.00	30.00
Field capacity (FC)	%	15.29	15.56	15.50	15.85
Wilting point (WP)	%	7.32	7.53	7.33	7.50
Bulk density (ρb)	Mg m^{-3}	1.71	1.75	1.69	1.73
Particle density (ρs)	Mg m^{-3}	2.63	2.69	2.66	2.71
$CaCO_3$	g kg^{-1}	46.15	50.00	46.70	51.85
Soil reaction (pH, 1: 2.5)	---	7.94	7.98	8.05	8.08
Electrical connectivity	dS m^{-1}	7.15	6.56	7.10	6.65
Organic matter	g kg^{-1}	1.73	1.40	1.80	1.40
Available-N	mg kg^{-1}	30.7	29.35	31.20	30.20
Available-P	mg kg^{-1}	6.3	6.5	6.4	6.45
Available-K	mg kg^{-1}	122	117	127	119

The experimental plots (5 × 8 in width and length) with an area of 40 m^2 were laid out in a completely randomized block design (RCBD) in triplicates and were bounded with a buffer zone (2 m width) to avoid the horizontal water seepage. The present study was conducted to investigate the impact of different soil organic amendments *i.e.*, humic acid (HA) and molasses (Ms), applied at 0.25 and 0.50% (v/w) on soil properties, nutrient status, and on growth and productivity of wheat. In addition to the above-mentioned treatments, control plots were also included with no addition of any soil amendment. The HA and Ms were supplied by Sohag governorate and added at 0.25 and 0.50% (v/w) to the soil with irrigation water. The chemical analysis of the tested soil amendments is presented in Table (3).

2.2 Field preparation

During the winter seasons of 2017-18 and 2018-19, wheat seeds were sown in rows 800 cm long and 15 cm apart on November 20 under flooding irrigation methods (each plot included 33 rows). All the recommended agricultural practices were performed as commonly used for growing wheat and carried out according to the recommendations set by the Ministry of Agriculture. Nitrogen (N) fertilizer was applied as ammonium nitrate at 120 kg $feddan^{-1}$ (1 feddan = 0.42 hectare) in two equal doses, the first one before the post-planting irrigation, and the second dose at the tillering stage (before the second irrigation). Phosphorus (P) was applied in the form of calcium superphosphate at 100 kg $feddan^{-1}$ at one time during soil preparation. For potassium (K), potassium sulfate at 50 kg $feddan^{-1}$ was added in two equal portions at the same time as added nitrogenous fertilizer. Harvesting of wheat was 135 days after planting during both seasons.

2.3 Data collection

2.3.1 Growth and yield parameters

At harvest time, plant height from five plants in each plot was measured using a meter rod and the average was calculated. For seed index, 1000 grain weight was measured by using a digital balance. The data regarding grain and straw yield was calculated from the four-square meters (2m × 2m) centric area of each plot and later on converted tons per hectare basis. Dried grounded grain of 0.25 g was digested using 10 mL of a mixture of 7:3 ratio of sulfuric to perchloric acids (Jackson, 1973), then were analyzed for the total N, P, and K contents.

Table (3): Chemical properties organic amendments used in the present study.

Material	EC (dS m^{-1})	pH	OM (g kg^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})
Humic acid (HA)	12.80	8.95	40.0	13.00	10.00	25.00
Molasses (Ms)	10.70	5.40	350.0	41.50	0.80	24.00

2.3.2 Post-harvest soil analysis

After harvesting wheat crop, soil samples from disturbed and undisturbed soil were collected from the plots of each treatment at depths 0-30 and 30-60 cm and analyzed in the laboratory for soil physico-chemical features. The disturbed soil samples were air-dried, gently crushed, and sieved through a 2.0 mm sieve. The soil chemical properties were measured according to (Page 1982), and the physical properties were carried out according to (Klute, 1986). Soil reaction (pH) was measured by a digital pH meter in 1:2.5 (soil: water) suspension, and the electrical conductivity (EC) was measured in 1:1 extract using the salt bridge method. Soil organic matter was determined by the wet oxidation method by $K_2Cr_2O_7$ 1 N and H_2SO_4 (Baruah, 1997). Total and available nitrogen was determined using the micro-Kjeldahl method, and the available potassium was measured by flame photometer according to Jackson (1973). The available phosphorus was measured according to (Olsen, 1954), while total phosphorus was measured according to Nelson (1982).

2.4 Statistical analysis

The analysis of variance (ANOVA) and Duncan's multiple range test were used to determine the statistical differences between the impact of the applied treatments on soil physicochemical properties and yield data using CoStat software, at $\alpha = p < 0.05$. All the results have been presented as mean values (n = 3) ± standard deviation (SD).

3. Results

3.1 Impact of different soil organic amendments on soil properties

3.1.1 Physical properties

The impact of humic acid (HA) and molasses (Ms) application at different levels *i.e.*, 0.25 and 0.50% (v/w) on soil physical properties is shown in Table (4) and Table (5). The effect was more obvious in the surface layer than in the subsurface one and with increasing the application rate. Soil bulk density (BD) and total porosity values were affected by the application of different soil organic amendments especially in the surface layer with the higher application rate (Table 4). As average values of both seasons, the relative reductions in BD values in the surface layer were 15.26 and 16.14% with the application of HA and Ms at 0.25%, respectively as compared to the control (CK). The corresponding values were 16.94 and 17.86% with the application of HA and Ms at 0.50%, respectively in comparison to the control. HA and Ms application at the rate of 0.25% increased the total porosity in the surface layer by 15.26 and 16.13%, while it increased by 16.94 and 19.33% at the rate of 0.50% compared to control treatment, respectively. The application of Ms revealed the greatest positive effect especially with the higher rate and in the surface layer than the HA treatments. Regarding the water related parameters under investigation, the application of soil amendments caused a slight change in the saturation percentage (SP) value (Table 5). The data revealed that the relative increases of SP due to 0.25% rate in the surface layer were 17.42 and 23.88% with the application of HA and Ms, respectively than the control.

Table (4): Impact of different organic amendments on bulk density, and porosity of soil after the growing seasons of 2017-2018 and 2018-2019.

Treatments	Rate (%)	Depth (cm)	Bulk density (Mg m^{-3})		Porosity (%)	
			2017-2018	2018-2019	2017-2018	2018-2019
CK		0-30	1.62±0.03a	1.62±0.03a	38.20±0.95e	38.71±0.60d
		30-60	1.72±0.4a	1.73±0.02a	35.18±0.40f	35.43±0.69e
HA	0.25	0-30	1.43±0.02c	1.44±0.04c	44.52±0.69bc	44.13±0.49b
		30-60	1.57±0.02b	1.58±0.02b	40.64±0.71d	40.13±0.69c
	0.50	0-30	1.42±0.04c	1.40±0.04c	44.69±0.45b	45.25±0.30a
		30-60	1.56±0.02b	1.57±0.02b	40.10±0.65d	39.08±0.48d
Ms	0.25	0-30	1.41±0.04c	1.43±0.03c	44.78±1.10c	44.54±0.63b
		30-60	1.54±0.04b	1.55±0.02b	40.38±0.40d	39.41±0.25cd
	0.50	0-30	1.39±0.03c	1.40±0.04c	45.92±0.35a	45.86±0.63ab
		30-60	1.53±0.05b	1.52±0.04b	41.64±0.52d	40.98±0.40d

Where CK = Control (no amendments applied), HA = Humic acid, Ms = Molasses applied at 0.25 and 0.50% (v/w). All values are the mean of three replicates ± standard deviation. Within each column, the values followed by the same letter are not statistically different at $P < 0.05$.

Using the higher rate (0.5%) resulted in the increment of SP by 21.39 and 26.36% over the control treatment. For all the treatments, field capacity (FC) of the sub-surface layer was less affected than the surface layer, and the effect of HA was evident at a higher rate, while the opposite trend was noticed with the application of Ms. In both the growing seasons, the relative change of FC in the surface layer at a high rate was increased by 10.12 and14.42% with the application of HA and Ms, respectively. The corresponding values of wilting point (WP) using the highest rate in the surface layer were 20.44 and 25.42% for HA and Ms, respectively over the control.

3.1.2 Hydraulic properties

In both growing seasons, the application of soil amendments increased the soil hydraulic conductivity (HC) and infiltration rate (IF) values compared to the control treatment (Table 6). In general, the HC values of topsoil (60 cm) differed from 0.10 to 0.41 m day-1, and the IF values varied from 0.16 to 0.36 cm h-1 as average values of both seasons. The HC increased as the amount of soil amendments increased. According to O'Neal (1952), the HC was considered moderately slow for the application of HA and Ms, and slow for the control treatment.

Table (5): Impact of different soil organic amendments on saturation percentage (SP), field capacity (FC), wilting point (WP), and available water contents (AWC) after the growing seasons of 2017-2018 and 2018-2019.

Treatments	Rate (%)	Depth (cm)	SP (%)		FC (%)		WP (%)		AWC (%)	
			2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019	2017-2018	2018-2019
CK		0-30	33.00±1.0d	34.00±1.02c	19.17±0.76b	19.18±0.55d	8.75±0.44e	8.52±0.63e	10.42±0.56c	10.67±0.59c
		30-60	33.33±0.58d	31.67±0.68d	19.25±0.30b	18.22±0.35d	8.95±0.40e	8.00±0.25e	10.30±0.65c	10.22±0.55c-e
HA	0.25	0-30	39.00±1.0b	39.67±1.35b	20.60±0.60b	21.63±0.48bc	9.47±0.20cd	9.70±0.44d	11.13±0.70b	11.93±0.57ab
		30-60	39.67±1.53b	38.33±0.68b	20.73±1.12b	21.58±0.81bc	9.98±0.13bc	10.03±0.20b-d	10.75±1.18b	11.57±0.88b
	0.50	0-30	39.33±1.45b	42.00±1.50a	21.42±0.84a	22.67±0.65a	10.32±0.74ab	10.48±0.50a-c	11.10±0.66b	12.2±0.38a
		30-60	35.67±0.58c	38.00±1.0b	20.78±0.70b	21.37±0.40c	9.20±0.18d	9.67±0.38d	11.58±0.52b	11.73±0.43ab
Ms	0.25	0-30	41.33±1.25a	41.67±0.75a	22.00±0.46b	21.88±0.30a	10.13±0.21ab	10.57±0.39a-c	11.87±0.38a	11.31±0.67b
		30-60	38.67±0.68b	38.67±1.10b	20.37±0.51b	21.38±0.29c	9.97±0.23bc	9.92±0.38cd	11.40±0.63b	11.47±0.57b
	0.50	0-30	42.33±1.42a	42.33±0.65a	22.80±0.35b	22.78±0.33ab	10.68±0.45a	10.98±0.44a	12.12±0.41a	11.80± 0.62a
		30-60	41.33±0.78a	42.00±1.0a	21.42±0.26b	21.88±0.28c	10.35±0.18ab	10.73±0.28ab	11.07±0.31b	11.15±0.21b

Where CK = Control (no amendments applied), HA = Humic acid, Ms = Molasses applied at 0.25 and 0.50% (v/w). All values are the mean of three replicates ± standard deviation. Within each column, values followed by the same letter are not statistically different at $P < 0.05$.

Also, the infiltration rate is considered slow for the application of HA and Ms according to Hillel (1982). The impact of the application of HA and Ms on soil infiltration rate could be arranged in the descending order of Ms > HA.

3.1.3 Soil chemical properties

The soil reaction (pH), soil salinity (EC), and organic matter (OM) values as affected by the application of different soil organic amendments after harvesting of the wheat during the growing season of 2017-18 and 2018-19 (Table 7). The pH reduction varied according to soil amendment types, its application rates as well as soil layer. The decrease was more pronounced with the HA application whatever its rate. The soil pH values of the surface layer (0-30) were lower than that of sub-surface one (30-60) for all soil organic amendments and their rates. Except for the application of HA at a high rate in both soil layers, the applied soil amendments and their rates caused a reduction of the soil pH and EC values compared to the control. Among all soil amendments, Ms was the more effective one in reducing soil salinity because its EC contents were lower than HA (Table 3).

Table (6): Impact of different soil organic amendments on hydraulic properties of soil after the growing seasons of 2017-2018 and 2018-2019.

Treatments	Rate (%)	Hydraulic conductivity (m day^{-1})				Soil infiltration (cm h^{-1})			
		2017-2018		2018-2019		2017-2018		2018-2019	
		Value	Category	Value	Category	Value	Category	Value	Category
CK		0.10±0.01c	S	0.14±0.01d	S	0.17±0.01c	S	0.16±0.02d	S
HA	0.25	0.32±0.03b	MS	0.32±0.02c	MS	0.24±0.02b	S	0.25±0.01c	S
	0.50	0.35±0.02ab	MS	0.36±0.02b	MS	0.30±0.03a	S	0.31±0.02b	S
Ms	0.25	0.34±0.05b	MS	0.38±0.03ab	MS	0.34±0.01a	S	0.32±0.01b	S
	0.50	0.40±0.02a	MS	0.41±0.02a	MS	0.32±0.02a	S	0.36±0.02a	S

Where CK = Control (no amendments applied), HA = Humic acid, Ms = Molasses applied at 0.25 and 0.50% (v/w), S = slow and MS = moderately slow. All values are the mean of three replicates ± standard deviation. Within each column, values followed by the same letter are not statistically different at $P < 0.05$.

Table (7): Impact of different soil organic amendments on soil reaction (pH), electrical conductivity (EC), and organic matter (OM) in the soil after the growing seasons of 2017-2018 and 2018-2019.

Treatments	Rate (%)	Depth (cm)	pH		EC (dS m^{-1})		OM (g kg^{-1})	
			2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
CK		0-30	7.75±0.07a	7.75±0.07a	4.76±0.05d	5.57±0.20cd	4.0±0.20de	4.4±0.20f
		30-60	7.77±0.07a	7.76±0.07a	5.26±0.20c	5.60±0.21cd	1.9±0.10f	2.0±0.30g
HA	0.25	0-30	7.58±0.06d	7.64±0.09ab	4.47d±0.11ef	5.49±0.08d	7.9±0.40b	8.4±0.40b
		30-60	7.66±0.07bcd	7.64±0.08ab	4.27±0.08efg	5.79±0.04c	5..03±0.10d	4.97±0.23ef
	0.50	0-30	7.62±0.07cd	7.58±0.04b	7.46±0.07a	7.20±0.05a	9.67±0.20a	9.73±0.15a
		30-60	7.63±0.06cd	7.62±0.10ab	6.58±0.21b	6.84±0.12b	6.1±0.10c	6.4±0.25cd
Ms	0.25	0-30	7.65±0.06cd	7.66±0.05ab	3.93±0.11g	4.52±0.19f	6.7±0.30c	7.0±0.12c
		30-60	7.74±0.01ab	7.71±0.02ab	4.12±0.15fg	4.73±0.10ef	5.0±0.10d	5.3±0.30def
	0.50	0-30	7.63±0.02cd	7.60±0.03ab	4.71±0.35de	5.60±0.13cd	8.3±0.20b	8.5±0.51b
		30-60	7.74±0.03ab	7.73±0.04ab	3.86±0.51g	4.87±0.15e	5.5±0.2d	5.9±0.23de

Where CK = Control (no amendments applied), HA = Humic acid, Ms = Molasses applied at 0.25 and 0.50% (v/w). All values are the mean of three replicates ± standard deviation. Within each column, the values followed by the same letter are not statistically different at $P < 0.05$.

Table (8): The effect of soil amendments application on the availability of soil nitrogen (N), phosphorus (P) and potassium (K) (mg kg^{-1}) after two successive seasons (2017/18-2018/19).

Treatments	Rate (%)	Depth cm	N		P		K	
			2017/18	2018/19	2017/18	2018/19	2017/18	2018/19
CK		0-30	43.83±1.0h	47.57±0.51h	8.62±0.13f	8.66±0.05f	187.00±10.4cd	184.67±4.51d
		30-60	38.17±0.29i	39.17±0.76i	7.64±0.14g	7.74±0.16g	187.33±4.62cd	188.33±2.89cd
HA	0.25	0-30	53.55±0.51d	56.43±0.61d	11.16±0.09b	11.03±0.26b	210.00±13.23ab	199.83±5.21b
		30-60	47.70±0.61g	48.70±0.55g	9.27±0.33e	9.42±0.08e	188.33±4.73cd	193.67±4.04bc
	0.50	0-30	55.45±0.51c	58.77±0.49c	11.55±0.18a	12.09±0.21a	219.67±5.29a	208.00±5.06ab
		30-60	48.77±0.68f	49.73±0.64f	10.05±0.08c	10.01±0.18d	187.33±5.03cd	198.33±3.51b
Ms	0.25	0-30	63.63±0.32b	61.45±0.51b	9.76±0.24d	9.48±0.21e	209.17±5.01ab	215.67±8.14a
		30-60	50.51±0.43e	49.93±0.12ef	8.44±0.18f	8.47±0.30f	198.00±2.65bc	201.33±3.43b
	0.50	0-30	68.53±0.50a	68.15±0.18a	10.32±0.27c	10.40±0.14c	212.67±9.29a	213.67±7.09a
		30-60	50.42±0.40e	50.82±0.28e	9.13±0.10e	9.28±0.18e	191.33±7.15cd	201.67±4.08b

CK, Control (no amendments applied), HA, Humic acid, Ms, Molasses, at rate of 0.25 and 0.50%.All values are the mean of three replicates analysis ±standard deviation. Within each column, values followed by the same letter are not significantly different at $P<0.05$ level. Least significant difference (LSD) value ($p < 0.05$) of probability using CoStat software.

The results also clearly showed that soil amendments remained effective in increased OM contents compared to the control. These increases were more pronounced with adding HA than other treatments. The magnitude of increment of OM varied according to soil amendment types, their application rates as well as soil layer. In general, the high rate of HA and Ms increased OM content by 1.31 and 1.00 times in the surface layer. Moreover, the low rate of soil amendments application led to an increase in the OM by 0.94 and 0.63 times in the surface layer. The available nitrogen (N), phosphorus (P), and potassium (K) were significantly ($P < 0.05$) increased due to the addition of soil amendments compared to the control (Table 8). The level of those nutrients varied according to amendments types, application rates, and soil layers. The highest N availability was recorded by adding Ms than the other treatments, while the availability of P and K were more pronounced with the HA application than that of the application of Ms. All the soil amendments at various application rates increased the availability of N, P and K in the surface layer than the sub-surface one. On the average basis, all soil amendments at different application rates increased the available P in the surface layer, and it was higher than the sub-surface one.

3.2 Impact of different soil organic amendments on growth, yield, and nutrient contents of wheat

3.2.1 Growth and yield parameters

The plant height and wheat seed index (1000 grain weight) were significantly increased with the application of different soil organic amendments compared to the control (Figure 1).

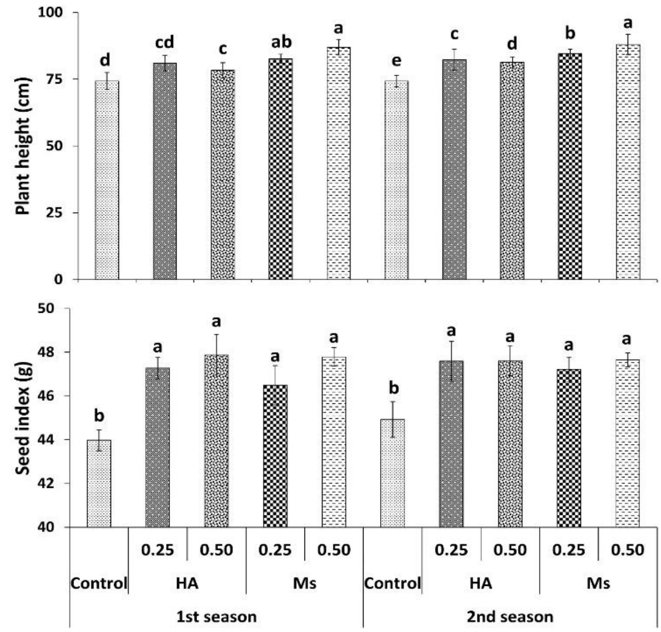

Figure (1): Impact of humic acid (HA) and molasses (Ms) applied at 0.25 and 0.50% (v/w) on plant height (cm) and seed index (g) of wheat during first (2017-18) and second season (2018-19). Different lower-case letters above the column indicate a significant difference between treatments at $p< 0.05$.

The magnitude of increase varied due to organic amendment types and their application rates. The lower rate of organic amendments was more effective in increasing the plant height and seed index than the higher one. However, the greatest plant height was recorded with the lower HA rate which was 16.59% higher than the control. On the other hand, the high rate of HA recorded the maximum increment of the seed index followed by the high rate of Ms than the other treatments. In addition, these organic materials increased the total dry grain and straw yield, and the increments were more pronounced with the higher rate of organic amendments (Figure 2). The application of Ms proved superior to HA for increasing the dry grain and straw yield, especially with the high rate. The higher rate of HA and Ms increased the grain yield by 4.53 and 35.39% than the control, respectively. The corresponding values of the straw yield were 15.80 and 113.01% at a high rate.

3.2.2 Nutrients content in grain

The results indicated that there was a significant increase of N, P, and K in grain as a result of applying different soil amendments compared to the untreated one (Figure 3).

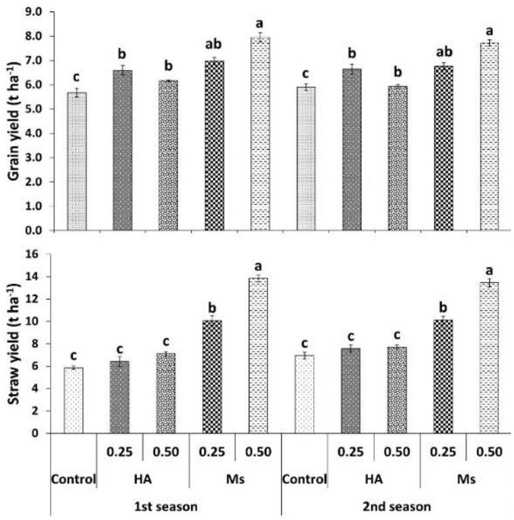

Figure (2): Impact of humic acid (HA) and molasses (Ms) applied at 0.25 and 0.50% (v/w) on grain and straw yield (t ha^{-1}) of wheat during the first (2017-18) and second season (2018-19). Different lower-case letters above the column indicate a significant difference between treatments at $p< 0.05$.

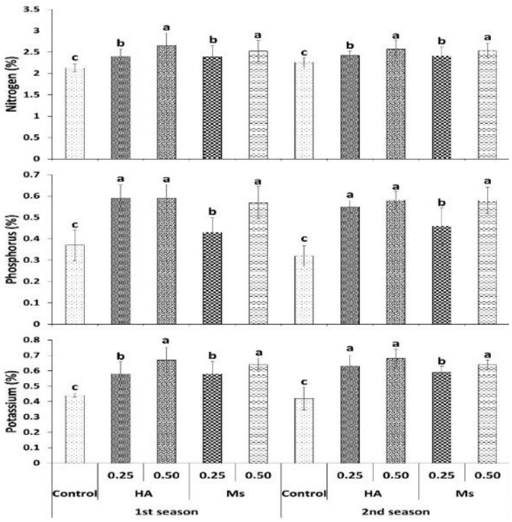

Figure (3): Impact of humic acid (HA) and molasses (Ms) applied at 0.25 and 0.50% (v/w) on nitrogen, phosphorous, and potassium contents (%) in wheat grains during first (2017-18) and second season (2018-19). Different lower-case letters above the column indicate a significant difference between treatments at $p< 0.05$.

The magnitude of increase relied on amendment type and its application rate. Increasing the application rate led to an increase in the nutrient contents of wheat grains, and the HA remained superior over Ms. As a result of adding the high rate of HA, the N, P, and K contents in grains were increased by 19.13, 69.57, and 56.98%, respectively compared to the control treatment. The corresponding values of these nutrients due to the high rate of Ms were 15.03, 66.67, and 48.84%, respectively.

4. Discussion

4.1 Soil physical properties

In agreement to our findings, previously it has been reported that organic materials addiiton improved soil aeration, reduced soil bulk density, and enhanced water infiltration and retention (Agbede *et al*., 2013). The observed decrease in soil BD was might be due to the application of organic amendments properties such as particle size, active surface area, and porosity etc. However, the ability of organic materials to form the soil aggregates in combination with soil particles leads to a decrease in soil BD values (Šimanský *et al*., 2016). It was also noticed that soil porosity was increased as soil BD decreased. This fact strictly corresponds to the observed BD values. Miglierina *et al*. (2015) found that the application of organic materials lowered soil BD and increased soil porosity. In the present study, reduction of soil BD and increase in the total porosity was more noticed with the highest application rate. Šimanský (2016) concluded that the porosity increased as a result of the higher application rate of soil amendments which improved the soil structure. Furthermore, one of the most important mechanisms of the soil structure formation that has significantly increased total porosity with the organic material application may be the ability of organic material itself to associate with the soil mineral particles directly (Lehmann *et al*., 2011), and/or through Ca bridges (Kobierski *et al*., 2018; Šimanský and Jonczak, 2020). In this regard, Toková *et al*. (2020) found that biochar applied at 20 ton ha^{-1} without fertilizer significantly reduced the BD by 12%, and increased the soil porosity by 13%. It was also found that a gradual increase in the biochar rate gradually decreased the bulk BD and total porosity. Also, Alagöz and Yilmaz (2009) indicated that the increase in the soil organic matter content improved soil ventilation and aggregation, thus benefiting crop growth and yield. Optimum availability of soil water is essential for proper plant growth and its development. Soil moisture constants such as saturation percentage (SP), field capacity (FC), and wilting point (WP) are necessary to determine the moisture present in soil under any certain condition and at any instant of time. The movement of soil water is mainly of three types viz. saturated, unsaturated, and water vapor movement. Infiltration and other modes of water entry into the soil contribute to the formation of water reservoirs in soil (Chauvin *et al*., 2011). Also, Habashy and Ewees (2011) found that the addition of organo-mineral fertilizer (OMF) compost to saline soil encouraged the creation of medium and micro-pores (*i.e*., water holding capillary, WHC, and useful pores) between simple packing sand particles, and in turn, increased the capillary potential. The above-mentioned case is more attributed to an increase in soil moisture content at field capacity and then available water content due to the increased content of total fibers (32.3-33.1%) and also the increased WHC of OMF compost (6.18-6.32 g water g^{-1} OMF compost). The effects of OMF components on improving soil properties such as aggregation, aeration, permeability, and WHC were positive, which led to maintaining the appropriate water content in the soil and hence increased the activity of the immune to the plant system. Soil moisture is an important control of hydrologic function, as it governs vertical fluxes from and to the atmosphere, groundwater recharge, and lateral fluxes through the soil. Soil hydraulic properties are essential in irrigation and drainage studies for closing water balance equations, for predicting leaching of nutrients, for water supply to plants, and other agronomical and environmental applications (Vereecken *et al*., 2008).

4.2 Soil chemical properties

The organic amendments application slightly affected the soil reaction (pH), electrical conductivity (EC), and organic matter (OM). The slight change in the pH values may be due to the soil buffering capacity to resist the change. The decomposition of Ms has been reported to release the compounds belonging to the carboxylic groups which, after dissociation may decrease soil pH. As soon as these groups are decarboxylated in the citrate cycle, an equivalent amount of protons is required inducing a rise in soil pH (Abo-Baker, 2017). Also, Mairan *et al*. (2005) found that the noticeable reduction in soil pH is due to long-term manuring and fertilization. In addition, Pyakurel *et al*. (2019) concluded that the application of molasses and organic fertilizer increases the soil organic carbon, nitrogen, potassium whereas molasses reduces soil reaction (pH). Molasses stimulates the production of organic acids in the soil which helps to decrease soil pH. These results are compatible with those obtained by Awad *et al*. (2021) and Awad *et al*., (2020a) who reported that the application of humic acid and sugar can vinasse decrease the pH value of different soils. The results showed a decrease in electrical conductivity (EC) as a result of organic amendments application, and the effect was more pronounced with the high rate. The decrease in soil salinity as a result of the materials additions may be due to the improvement of the soil physical properties which may facilitate the movement of water down to the lower layers, and thus a decrease in the electrical conductivity values in the upper layers occurred. This result is in agreement with that observed by (Awad *et al*., 2020b) which found that the value of electrical conductivity decreased with the addition of bamboo biochar at rates of 2, 4, and 6% and the lowest rate of garden biochar (2%) in comparison to soil control. Soil organic matter (SOM) is the most important constituent that influences soil fertility, soil formation, soil biology, physical and chemical soil properties which in turn reflects on crop production (Walker *et al*., 2004). However, the soil organic matter value was increased due to the addition of the amendment in the surface layer more than the sub-surface one, especially at the high rate. This result may be due to the high organic matter content of these amendments which was more declared with the high rate. Similar results were obtained by Ali *et al*. (2021), Awad (2016), Rekaby *et al*. (2020), and Rekaby *et al*. (2021) who concluded that the organic matter gradually increased with increasing the organic materials application level compared to control in the tested soils. Also, Chen *et al*. (2014) indicated that the addition of humic acid could enhance the content of soil organic matter.

4.3 Nutrient availability

Soil amendments hold potential to boost the supply of available nutrients in the soil solution for crop plants. For instance, humic acid being up a significant component of soil organic matter and can improve water-holding capacity, and act as a nutrient ‘reservoir’ by complexing macro-and micro-nutrients (Alagöz and Yilmaz, 2009). Also, this might be attributed directly to the nutrient addition as a result of adding soil amendments and indirectly to increase organic matter content which makes the nutrients more available. This result is coinciding with that obtained by (Chen et al. 2014) who reported that the addition of humic acid could enhance the nutrient content of the soil under continuous cropping peanuts which has the beneficial improvement of farmland soil. In the same trend, Li *et al*. (2019) found that humic acid increased soil nutrient contents (total and available N, P, and K) and organic matter contents, which exhibited the maximum effect in the third year and is conducive to long-term sustainable use of soil. Abo-Baker (2017) found that adding Filter mud cake, FYM, and molasses realized an increase in the soil nutrient availability and power supply of the soil occurred with the available N, P, and K.

4.4 Growth and yield traits of wheat

In many cases, low soil fertility is the limiting factor for plant growth especially in sandy soils (Arancon *et al*., 2006; Daws *et al*., 2013). Thus, increasing soil nutrients after the addition of soil amendments have been widely reported to improve plant growth and all plant parameters (Awad *et al*., 2017; Awad, 2018; Rekaby *et al*., 2020). In addition, the amendments were found to increase the ratios of above-ground biomass to root biomass that might be an indication of higher availability of soil nutrients (Yan *et al*., 2019). The application of organic amendment increased the growth and yield of wheat plants. The magnitude increase was varied according to amendment type and its application rate. The molasses was superior to that of humic acid, especially at a high rate. This might be attributed to the positive effect of more available nutrients and /or increasing water holding capacity at the grain filling stage which increases the starch content and organic component in wheat plants. These results coincide with those obtained by Khan *et al*. (2018) who reported that wheat grain yield is increased by11-21% in alkaline calcareous sandy loam soils over control as a result of fertilizers application with humic acids extracts derived from plant and coal materials.

4.5 Nutrient content of wheat grain

In our study, both organic amendments (molasses and humic acid) increased the nutrient contents in wheat grain and the highest contents were observed with the application of HA. It might be because HA contains high nutrients than Ms and/or to its role in increasing the absorption, and thus raising the nutrients contained in the wheat grain. These findings are in agreement with those recorded by Khattak and Muhammad (2008), who concluded that the application of HA can supply N and P to the plants as it is the primary constituent of organic carbon, N and P. Similar results were obtained by Chandraju *et al*. (2008) who indicated that the use of a diluted solution of molasses increased the uptake of nutrients and yield of leafy vegetables. Also, Khalil *et al*. (2006), and Ali *et al*. (2021b) reported that increased nutrient availability as a result of soil amendments addition led to an increase in the uptake, and thus an increase in the P contents in grains. Besides, an improvement in physicochemical properties such as an increase in organic matter consequently water holding capacity may explain the improvement in growth by taking up more P contents in plants and grains.

5. Conclusion

Our findings were in line with the postulated hypothesis as organic amendments remained effective regarding parameters under investigation. Results of the present study showed that soil hydro-physicochemical properties of the soil were improved by adding different soil organic amendments. The study verified that adding molasses as a soil amendment at 0.50% (v/w) was the best organic amendment for wheat that improved soil hydro-physical properties of the soil. It is, therefore, recommended that natural organic soil amendments such as humic acid and molasses could be a viable tool for the improvement and stabilization of coarse-textured, fragile, and low in organic matter soil. However, it is suggested to conduct further in-depth studies under varying pedo-climatic conditions by including more organic amendments for improving soil fertility and boosting wheat yield in a sustainable way under changing climate scenario.

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