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Poultry Manure and Its Derived Biochar as a Soil Amendment for Newly Reclaimed Sandy Soils under Arid and Semi-Arid Conditions

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Abstract**—**Sandy soils under arid and semi-arid conditions are characterized by poor physical and biochemical properties such as low water retention, rapid organic matter decomposition, low nutrients use efficiency, and limited crop productivity. Addition of organic amendments is crucial to develop soil properties and consequently enhance nutrients use efficiency and lessen organic carbon decomposition. Two years field experiments were developed to investigate the feasibility of using poultry manure and its derived biochar integrated with different levels of N fertilizer as a soil amendment for newly reclaimed sandy soils in Western Desert of El-Minia Governorate, Egypt. Results of this research revealed that poultry manure and its derived biochar addition induced pronounced effects on soil moisture content at saturation point, field capacity (FC) and consequently available water. Data showed that application of poultry manure (PM) or PM-derived biochar (PMB) in combination with inorganic N levels had caused significant changes on a range of the investigated sandy soil biochemical properties including pH, EC, mineral N, dissolved organic carbon (DOC), dissolved organic N (DON) and quotient DOC/DON. Overall, the impact of PMB on soil physical properties was detected to be superior than the impact of PM, regardless the inorganic N levels. In addition, the obtained results showed that PM and PM application had the capacity to stimulate vigorous growth, nutritional status, production levels of wheat and sorghum, and to increase soil organic matter content and N uptake and recovery compared to control. By contrast, comparing between PM and PMB at different levels of inorganic N, the obtained results showed higher relative increases in both grain and straw yields of wheat in plots treated with PM than in those treated with PMB. The interesting feature of this research is that the biochar derived from PM increased treated sandy soil organic carbon (SOC) 1.75 times more than soil treated with PM itself at the end of cropping seasons albeit double-applied amount of PM. This was attributed to the higher carbon stability of biochar treated sandy soils increasing soil persistence for carbon decomposition in comparison with PM labile carbon. It could be concluded that organic manures applied to sandy soils under arid and semi-arid conditions are subjected to high decomposition and mineralization rates through crop seasons. Biochar derived from organic wastes considers as a source of stable carbon and could be very hopeful choice for substituting easily decomposable organic manures under arid conditions. Therefore, sustainable agriculture and productivity in newly reclaimed sandy soils desire one high rate addition of biochar derived from organic manures instead of frequent addition of such organic amendments.

Keywords**—**Biochar, dissolved organic carbon, N-uptake, poultry, sandy soil.

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I. Introduction

ANIMAL organic wastes application to soils were always an important practice in agricultural lands across the world. It was stated that animal manures improve soil physical, chemical and biological properties and provide crops with nutrients. Applying PM directly on soil may result in some environmental fears such as pathogenic bacteria, leaching nitrogen and scarce contribution to stable SOC [20]. Also, organic materials i.e. crop residues, farmyard manure and PM are shortly broken down in soil particularly under arid conditions [7]. In this context, agricultural researchers are always seeking the best alternative for organic amendments such as farmyard and PM. Biochar derived from PM is considered as a good alternative soil amendment [20], [32]. The organic wastes consist of a labile carbon; however, biochar obtained from organic wastes considers as a source of stabile carbon [4], [21].

Biochar can be defined as a carbon rich product when biomass such as woods, manures or leaves is heated in a closed container with little or unavailable oxygen [23]. Biochar has many possible benefits, improves moisture retention which may reduce the demand for irrigation and make cropping more secure, boosts plant growth, increase and sustain crop yields, also help to improve problematic nutrient-poor soils [10]. Biochar, in last 10 years, has been wildly investigated for agricultural purposes in sandy soils under arid conditions by ways of considering it as a soil amendment, improving soil physical, chemical and biological properties [1], [5], [6].

The application of biochar with N fertilizer on a light soil within temperate climate increased spring barley yield by 30% compared to individual N fertilizer [14]. Biochar application at a rate of 25 t ha^{-1} and 50 t ha^{-1} in combination with urea (75 and 150 kg ha^{-1}) to calcareous soil under semi-arid conditions in a field experiment in Pakistan made a significant improvement in soil quality and maize yield [7]. Moreover, mineral N remained at the same concentration from first to second season regardless the rate of applied N fertilizer. In a greenhouse experiment, the obtained results by [20] concluded that applying biochar derived from PM or PM resulted in improvement of chemical properties of calcareous soil and increased N concentration of both maize and bean plants. Also, N concentration of lettuce plants was increased following biochar and PM applications [17]. Experiments with barley grown on a Nitisol in the highlands of Ethiopia showed that application of biochar obtained from acacia, compost and their mixture resulted in high uptake, agronomic and apparent recovery efficiency of applied N at similar N fertilizer rates [3].

Egypt has a problem with land resources and there is a continuous demand for expanding agricultural areas to feed ever-increasing population. Most of the available area for expanding agricultural activities are sandy soils characterized by poor physical and chemical properties and located in Egyptian western desert [5]. Rapid SOC depletion and low N use efficiency are the main constraints for crop production in these newly reclaimed sandy soils. Addition of high amounts of N fertilizers is a key factor of crop productivity but N in these soils is subject to be lost either by leaching or volatilization. Therefore, applying organic amendments is crucial to develop soil physical properties and consequently enhance N use efficiency and lessen organic carbon decomposition.

Nitrogen is one of the major essential nutrients for plants, important component of protein and almost all the indispensable processes in plants are associated with the latter [22]. Moreover, nitrogen plays a vital role in root growth stimulation, improve fruit quality and increase protein content of fodder crops [22]. It was reported that about 50-70% of applied N fertilizer subject to loss either directly through different ways, volatilization, leaching and denitrification or indirectly via microbial activities [18], [27]. Applying biochar derived from manures to sandy soils as a strategy for increasing nutrient use efficiency and decreasing carbon and nitrogen loss under arid and semiarid conditions needs more studies. Thus, biochar derived from organic wastes could be very hopeful choice for substituting easily decomposable organic manures [1], [24]. Few studies have been conducted to investigate the comparison between the effect of PM and its pyrolyzed product (biochar) on some soil physicochemical properties, soil nitrogen and carbon status and productivity of wheat and forage sorghum grown on newly reclaimed sandy soils located in the Egyptian Western Desert. Thus, the objectives of this study were to explore the possibility of using PMB compared to PM (PM) with different proportions of N fertilizer as a soil amendment for newly reclaimed sandy soils in a field experiment on Western Desert of Egypt.

II. Materials and Methods

A. Experimental Site

This study was conducted in two successive cropping seasons of 2015 and 2016 on a special farmer`s field at El-Minia Governorate in the Western Desert of Egypt. The area under investigation lies in arid region (28º18'16"N, 30º34'38"E) characterized with an evaporation rate of 4897.91 mm/year, annual rainfall ranges from 23 – 33 mm/year and the temperatures in winter varied from 5 to 20 ^{o}C with maximum temperature 42 ^{o}C in July according to data from Egyptian meteorological agency. The soil of the experimental site has a sand texture, pH 8.18, with an electrical conductivity 0.85 dS m^{-1} and SOC 0.19%. The physical and chemical properties of the studied soil are presented in Table I. Air-dried samples of PM and PMB (< 2 mm) were divided into two proportions. Analyses such as BD, pH, EC, OC and CEC were undertaken in the first proportion as described later for soil analyses. The second proportion was oven dried at 65 ^{o}C and digested using H_2SO_4 and H_2O_2 and analyzed according to the procedures described by [9] and [31] to determine N, P and K contents. Characteristics of PM and PMB are shown in Table I.

TABLE I
PHYSICOCHEMICAL CHARACTERISTICS OF SOIL, PM AND PMB

Property	Soil	PM	PMB
Sand (%)	89.7	-	-
Silt (%)	5.6	-	-
Clay (%)	4.7	-	-
Texture class	Sand	-	-
pH 1:2.5	8.18	5.62	6.9
EC dS m^{-1} (1:2.5)	0.85	1.73	2.17
SOC% (oxidized)	0.19	35.28	17.64
TN%	0.02	1.97	1.55
C/N	9.50	17.91	11.38
CEC ($cmol_c$ kg^{-1})	3.46	38.26	45.71
BD g cm^{-3}	1.59	0.53	0.25
ava. P (mg kg^{-1})	4.5	-	-
ava. K (mg kg^{-1})	65	-	-
P%	-	1.12	1.72
K%	-	1.34	1.95

B. PM and PMB Preparation

Air-dried stalk bases of date palm trees were sliced and crashed and then used as bedding material for poultry farming for 50 days in deep litter system. The bedding material was collected and stacked on the cropland to dry before its application as a PM to the soil. The air-dried PM was used as a feedstock for biochar production. The pyrolysis of PM was undertaken in a muffle furnace under limited supply of oxygen at 300 ^{o}C for 2 hours. The production yield of PMB was approximately 50% of the feedstock, namely 10 tons of biochar made out of 20 tons of PM. Finally, PMB was crashed and sieved through a 2-mm sieve before its application as a soil amendment.

C. Experimental Design

The field experiment layout included two organic amendments (PM and PMB) applied at the rates of 20 and 10 t h^{-1} respectively in combination with 5 levels of inorganic nitrogen fertilizer (0, 25, 50, 75 and 100% of the recommended dose) with a treatment (100% of the recommended dose of N alone) and a control treatment (no PM, PMB or N fertilizer). The organic amendments were incorporated into the top 20 cm of the studied soil ten days before the beginning of cropping cycle (wheat – forage sorghum). The field experiment was started on November 15th, 2015 with sowing wheat (*Triticum aestivum* L.) at a rate of 190 kg seeds ha^{-1} and followed by sowing forage sorghum (*Sorghum bicolor* L.) at a rate of 75 kg seeds ha^{-1}. The experimental unit was a plot of 2.5 m × 2 m in size, with three replicates in a complete randomized block design for each treatment. The recommended doses of NPK were respectively 285 kg N ha^{-1}, 74 kg P_2O_5 ha^{-1} and 57 kg K_2O ha^{-1} for wheat and 238 kg N ha^{-1}, 71.5 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1} for forage sorghum as recommended by the Ministry of Agriculture, Egypt. The used NPK commercial fertilizers were ammonium sulphates (20% N), superphosphate (15.5% P_2O_5) and potassium sulphates (48% K_2O). The sprinkler irrigation system was used and treatments layouts are shown in Table II.

TABLE II
ABBREVIATIONS OF THE STUDIED TREATMENTS

PM (t h^{-1})	PMB (t h^{-1})	N levels	Abbreviation
0	0	0	Control
0	0	100%	100% N
20	0	0	PM+0% N
0	10	0	PMB+0% N
20	0	25%	PM+25% N
0	10	25%	PMB+25% N
20	0	50%	PM+50% N
0	10	50%	PMB+50% N
20	0	75%	PM+75% N
0	10	75%	PMB+75% N
20	0	100%	PM+100% N
0	10	100%	PMB+100% N

D. Soil and Organic Amendments Analyses

Undisturbed and disturbed soil surface samples were collected from each plot by the end of cropping cycle (wheat – forage sorghum) to study treatment effects on soil physical and chemical properties. The samples were packed, transported to the laboratory, air dried and sieved through a 2-mm sieve before soil analyses. Undisturbed soil samples were collected using core method to determine bulk density, water holding capacity and FC [11]. The porosity was calculated using soil particle density of 2.65 g cm^{-3}. Particle size distribution was determined using the Bouyoucous hydrometer method according to [15]. Hydraulic conductivity (cm/h) was measured in the field using tension infiltrometer according to [33]. Chemical analyses such as SOC, total nitrogen (TN), cation exchange capacity (CEC), available phosphorous and potassium were determined using standard method according to [9] and Black et al., 1965. Mineral N was determined by steam distillation [29], DOC and DON were determined according to [35].

E. N-Uptake and Nitrogen Recovery

At physiological maturity of wheat and forage, sorghum plants in an area of 2 m^2 in the center of each plot were harvested to determine grain and straw yields of wheat, fresh and dry weights of forage sorghum. All obtained data were converted into kg per hectare. The nutritional status of the plants was checked by determine the content of nitrogen in plant leaves taken from all experimental plots during the productive phase (60 days after planting out). Plant leaves were analysed for N according to the procedures described by [9] and [31]. Nitrogen recovery (NR%) was calculated as the percent of N applied for each treatment where: NR% = [(Plant N uptake for each treatment (kg/plot) - Plant N uptake for control (kg/plot)) / Total N applied for each treatment (kg/plot)] × 100.

F. Statistical Analysis

The experimental design was a randomized complete block with three replicates, and all data were subjected to variance analysis test and differences among means evaluated using the Least Significant Differences (LSD) methods according to [16].

III. RESULTS AND DISCUSSIONS

A. Treatment Effects on Some Soil Physical and Hydro-Physical Properties

Organic manures and its derived biochars have been widely used to alleviate some poor sandy soil physical and hydro-physical properties such as low water retention, soil moisture, porosity and ineffective water use productivity especially in newly reclaimed sandy soils in Egypt. The effects of PM and its biochar (PMB) in combination with inorganic N levels on a range of soil physical properties including BD, porosity, WHC, FC and HC are presented in Table III. Data presented in Table III showed that both PM and PMB had significant influences upon bulk density (BD), porosity, water holding capacity (WHC), FC and hydraulic conductivity (HC). Generally, the addition of PM and PMB respectively at a rate of 20 and 10 t ha^{-1} to the investigated sandy soil significantly caused improvement in soil physical properties regardless the inorganic N levels.

Overall, the impact of PMB on soil physical and chemical properties was detected to be superior than the impact of PM albeit double applied amounts of PM. Three plausible explanations for the superiority effect of PMB over PM on the investigated soil physical and hydro-physical properties may be due to, 1) direct pore contribution from pores in biochar itself, 2) creation of accommodation pores between biochar and the adjacent soil, and 3) improving the persistence of soil pores due to more stabile organic carbon in biochar compared to PM [19]. Biochar is highly porous, therefore its application to sandy soil is considered to improve various soil physical properties such as bulk density, porosity, water retention, and hydraulic conductivity [26], [37].

The obtained data showed that soil BD significantly reduced in PM and PMB treatments by 9.14 and 17.35% over the control or 100% N treatments. On opposite tendency, porosity increased by an average of 13.75% and 26.25% as a result of applying PM and PMB to the soil, respectively. Also, PM and PMB significantly increased WHC as soil porosity changed and recorded a relative increase by 30.27% for PM and 60.61% for PMB. In addition, compared to soil untreated with PM and PMB, FC of the soil amended with PM and PMB increased respectively by 20.72 and 30.82%. Regarding hydraulic conductivity (HC), treating such sandy soil characterized by high HC with PM and PMB resulted in a significant decrease in HC. The obtained results showed that HC decreased by 9.43 and 11.84% in plots treated with PM and PMB, respectively.

TABLE III
EFFECTS OF PM, PMB INTEGRATED WITH INORGANIC N FERTILIZER ON SOIL PHYSICAL AND HYDRO-PHYSICAL PROPERTIES

Treatments	BD g cm^{-3}	Porosity $m^3\ m^{-3}$	WHC %	FC %	HC cm/hour
Control	1.58	0.40	21.32	10.45	42.6
100% N	1.59	0.40	21.16	10.21	42.2
PM+0% N	1.42	0.46	28.39	12.62	38.7
PMB+0% N	1.33	0.50	33.30	13.28	37.5
PM+25% N	1.45	0.45	27.03	12.82	38.1
PMB+25% N	1.31	0.51	34.93	13.55	37.3
PM+50% N	1.43	0.46	28.17	12.59	38.6
PMB+50% N	1.29	0.51	34.53	13.38	37.4
PM+75% N	1.44	0.46	27.94	12.27	38.4
PMB+75% N	1.30	0.51	33.93	13.85	37.2
PM+100% N	1.46	0.45	26.82	12.05	38.2
PMB+100% N	1.32	0.50	33.88	13.51	37.5
$L.S.D_{0.05}$	0.06	0.03	1.78	1.53	1.23

BD: Bulk density, WHC: Water holding capacity, HC: Hydraulic conductivity

Efficient management of soil moisture movement and retention is important issue for agricultural production in newly reclaimed sandy soils in view of water shortage and water loss under arid conditions. The effect of animal manures such as PM and PMB on soil physical properties has been widely studied. The addition of PM to soil enhanced soil organic matter, improved soil structure, bulk density, porosity, water holding capacity and hydraulic conductivity [2], [30]. Improvements in soil moisture constants could be due to increasing water holding pores and decreasing water loss by leaching and deep percolation after organic matter addition. Also, the higher values of soil porosity and lower values of bulk density for treated soils due to organic matter addition might induce higher soil capacity to absorb water and retain more water content [5], [8].

B. Effects on Soil Chemical Properties

Data presented in Table IV showed that application of PM, PMB and their integration with different levels of inorganic N resulted in significant changes on several soil properties such as pH, EC, mineral N, DOC, DON and DOC/DON ratio. Results indicated that sandy soil investigated was alkaline in soil reaction with safe limit of electrical conductivity. After soil treatment with PM and PMB, there was a decreasing tendency in soil pH in plots treated with PM followed by PMB due to pH of PM and PMB used in this study was 5.62 and 6.9, nevertheless such a significant decrease was not detected (Table IV). It is obviously that added amounts of PM and PMB were not enough to decrease soil pH significantly by the end of cropping season. The application of PM and PMB caused significant increases in EC of treated soil plots compared to untreated. This increase in soil EC obviously associated with the higher EC values of PM and PMB (1.73 and 2.17dSm^{-1}). Concerning the integration between organic amendments and inorganic N levels there was no significant differences in EC values among treatments except for treatments PM+75% N and PM+100% N compared to PMB+50% N and PMB+75% N. Generally, the EC values in plots either threated with PM alone or in combination with inorganic N levels were higher than those in plots treated with PMB (Table IV). This clearly attributed to the higher application rate (double rate) of PM yet the higher value of EC for PMB (2.17).

TABLE IV
EFFECT OF PM, PMB AND THEIR INTEGRATION WITH INORGANIC N FERTILIZER ON SOME SOIL CHEMICAL PROPERTIES

Treatments	pH	EC	SOC g kg^{-1}	Mineral N mg kg^{-1}	DOC mg kg^{-1}	DON mg kg^{-1}	DOC/DON
Control	8.15	0.87	2.07	13	28	5	5.6
100% N	8.19	0.94	2.11	39	39	9	4.3
PM+0% N	7.92	1.13	3.34	21	110	15	7.3
PMB+0% N	8.12	1.05	5.48	16	57	7	8.1
PM+25% N	7.98	1.15	3.16	30	105	16	6.6
PMB+25% N	8.05	1.11	5.26	23	54	8	6.8
PM+50% N	7.95	1.18	3.03	32	104	17	6.1
PMB+50% N	8.13	1.07	5.22	25	51	8	6.4
PM+75% N	8.00	1.21	2.78	35	101	18	5.6
PMB+75% N	8.10	1.06	5.12	30	48	7	6.9
PM+100% N	7.95	1.22	2.74	36	101	18	5.6
PMB+100% N	8.08	1.10	5.08	33	47	8	5.9
$L.S.D_{0.05}$	0.26	0.13	0.45	3.27	4.16	1.60	

EC: Electrical conductivity

By the end of cropping cycle SOC was significantly increased to an average of 3.01% for plots treated with PM and 5.25% for those treated with PMB compared to 2.09% for the control and 100% inorganic N treatments (Table IV). Nevertheless, the applied amount of PM was double the applied amount of PMB, the biochar increased SOC of sandy soil 1.75 times more than PM. This could be associated with the high carbon stability of biochar treated soils increasing soil persistence for decomposition in comparison with PM labile carbon. Also, one of the observations from the obtained data was regular decreases in SOC and increases in the C/N ratio as the applied amount of inorganic N fertilizers increased in combination with organic fertilizers. This may be illustrated with mineralization of organic amendments and immobilization of inorganic N. In this context, the obtained results showed that mineral N of plots treated with PM and

PMB progressively increased with the increase in applied amount of inorganic N (Table IV). Moreover, treatment of 100% N without any organic addition recorded the highest concentration of mineral N.

The nitrogen inputs into the investigated sandy soil through PM was nearly double (394 kg) PMB inputs (155 kg). Whereas, carbon inputs through PM (7060 kg) was much higher (nearly fourfold) than that of the PM biochar (PMB) due to manure double inputs and higher contents of carbon and nitrogen. Thus, always DOC and DON values were higher in all PM treatments than in PMB treatments. By contrast, always the quotient DOC/DON values were higher in all PMB treatments than in PM treatments, reflecting further increase in treated sandy soils C/N ratios by biochar addition compared to PM. Organic components such as DOC and DON are considered as labile organic substrates. Thus, the soil contents of DOC and DON are indicators for stability of organic amendments such as PM and PMB. Mean concentrations of DOC ranged from 47 to 110 mg kg^{-1} and DON from 7 to 18 mg kg^{-1} indicating considerable differences among treatments (Table IV). Contents of DOC and DON were significantly affected by the application of PM and PMB either alone or with inorganic N different levels in comparison with control.

The control treatment recorded a ratio of DOC/DON 5.6 and in plots treated with full doses of inorganic N recorded the lowest ratio 4.3 due to increased levels of inorganic nitrogen. In Egypt, organic manures characterized by labile organic carbon, applied to sandy soils under arid and semi-arid conditions are always subject to high decomposition and mineralization rates through short growing cropping seasons. Therefore, sustainable productivity in sandy soils desires frequently addition of such organic amendments. However, biochar obtained from organic wastes considers as a source of stabile carbon [4], [21].

A better understanding of soil organic matter (SOM) dynamics is needed to improve management of SOC and nitrogen. DOC, organic carbon that can pass through 0.4-0.6 μm membrane filter [12], usually used to measure the DOM. DOC characterized by mobility, thus DOC plays a vital role in transporting nutrients [34], [36]. Due to its mobility, DOC plays an important role in transport of nutrients and pollutants such as nitrates and heavy metals. In a 44-day aerobic incubation experiment that the application of PM to a sandy loam soil resulted in an increase of DOC concentrations [28]. Mixing biochar with pure sand at a rate from 2 to 10 wt.% increased the cumulative loss of DOC compared to untreated sand, however only 0.06 – 0.18% of biochar carbon was transported to ground water and streams as DOC for all rates [25].

C. Treatment Effects on Wheat and Forage Sorghum Yield and Nutritional Status

The application of PM and PMB without any addition of inorganic N fertilizer significantly improved the growth of wheat in comparison with control (Table V). The grain and straw yields were significantly increased by 62.35 and 77.75% for PM, but increased by 35.66 and 47.84% for PMB, relatively to control. Addition of inorganic N fertilizer in combination with both PM and PMB resulted in significant increases of the grain and straw yields. The latter were gradually increased as the amount of inorganic N fertilizer increased. Plots treated with PM alone exposed higher relative increases in grain and straw yields of wheat than those treated with PMB (Table V). The higher yields of grain and straw were recorded with PM+100% N treatment. On the other hand, using the full dose of inorganic N without any organic amendments additions and relatively to control recorded increases of grain and straw yields by 133.63 and 123.82%. These increases were achieved in plots treated with PM at 50% of the full dose of inorganic N and in plots treated with PMB at 75% of the full dose of inorganic N.

Regarding the fresh and dry weights of forage sorghum (4 cuts), all treatments caused significant increases in fresh and dry weights (Table V). Relatively to control, the full dose of inorganic N increased fresh and dry weights of forage sorghum by 24.12 and 22.94%. The fresh weight of sorghum plants respectively increased by 13.35, 18.46, 30.95, 41.23 and 47.32% for PM and its combinations with inorganic N levels, however relevant increases caused by PMB along with inorganic N levels were 5.11, 16.62, 18.83, 24.86 and 26.46%. On the other hand, the dry weight of sorghum plants respectively increased by 15.65, 22.15, 32.23, 42.44, 50.80% for PM and its combinations with inorganic N levels, however relevant increases caused by PMB along with inorganic N levels were 8.36, 15.38, 19.89, 36.87 and 41.11%. The statistical analysis showed no significant differences among means of forage sorghum dry weight for treatments PM+75% N, PMB+75% N, PM+100% N and PMB+100% N.

TABLE V
EFFECT OF PM, PMB INTEGRATED WITH INORGANIC N FERTILIZER ON WHEAT AND FORAGE SORGHUM YIELD

Treatments	Wheat		Forage sorghum	
	Grain yield, kg h^{-1}	Straw yield, kg h^{-1}	Fresh weight, kg h^{-1}	Dry weight, kg h^{-1}
Control	1123.72	1313.62	36175	6940
100% N	2625.38	2940.43	48005	9270
PM+0% N	1824.32	2335.13	43839	8720
PMB+0% N	1524.45	1942.15	40650	8170
PM+25% N	2151.44	2745.24	45815	9210
PMB+25% N	1724.45	2264.2	45101	8700
PM+50% N	2968.82	3538.83	50646	9970
PMB+50% N	2068.37	2796.44	45958	9040
PM+75% N	3445.21	3758.72	54621	10740
PMB+75% N	2589.02	3433.04	48291	10320
PM+100% N	3736.24	4115.68	56977	11270
PMB+100% N	2827.27	3780.06	48909	10640
$L.S.D_{0.05}$	303.92	542.1	4057.33	984.89

The increase in yields of both crops over the control as a result of direct and residual effects of inorganic N may be due to higher N availability at vital growth periods, more biosynthesis of carbohydrates and their translocation. It is noticed that the increase in yield as a result of integration between either PM or PMB and inorganic N was more at the higher N levels and less at the lower ones. This might be attributed to the fact that the higher levels of inorganic N rush the mineralization of organic N which reflected on yield. Biochar application in combination with urea (75 and 150 kg ha^{-1}) to calcareous soil under semi-arid conditions in a field experiment in Pakistan made a significant improvement in soil quality and maize yield. The application of biochar with N fertilizer on a sandy soil increased spring barley yield by 30% compared to individual N fertilizer [14].

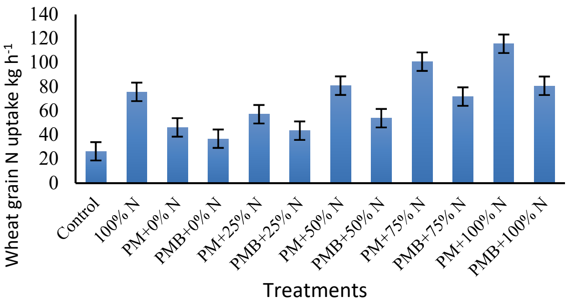

Fig. 1 Effect of PM and PMB integrated with inorganic N fertilizer on wheat grain N-uptake

Application of PM, PMB and their integration with different inorganic N levels significantly increased N uptake by grains of wheat and forage sorghum plants in comparison with control treatments (Figs. 1 and 2). Soil plots treated with PM alone recorded 46.16 kg h^{-1} N uptake compared to 36.74 kg h^{-1} for plots treated with PMB. Considering the levels of inorganic N, the grain N uptake was significantly increased as the applied amount of inorganic N increased. The obtained data showed that there was no significant difference in N uptake between plots fertilized by full recommended dose of inorganic N (75.61 kg h^{-1}) and those treated with PM at 50% of inorganic N recommended dose (80.75 kg h^{-1}). However, insignificant difference in N uptake between plots treated with PMB and those fertilized by full recommended dose of inorganic N was observed at 75% of inorganic N recommended dose (71.72 kg h^{-1}).

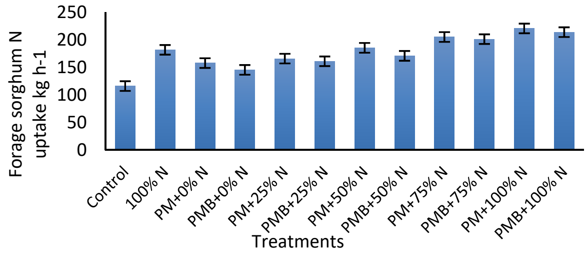

Fig. 2 Effect of PM and PMB integrated with inorganic N fertilizer on forage sorghum N-uptake

Total applied N (kg h^{-1}) to the investigated soil from PM, PMB and inorganic nitrogen fertilizer for each treatment is presented in Table VI. The impact of PMB on nitrogen recovery was detected to be greater than the impact of PM. The obtained data showed that nitrogen recovery significantly reduced in PM and PMB treatments over 100% N treatments but significantly increased over the control. Generally, the addition of PM and PMB respectively at a rate of 20 and 10 t ha^{-1} to the investigated sandy soil caused significant decreases in nitrogen recovery regardless the inorganic N levels. The obtained results showed almost the same changes in N uptake by forage sorghum plants. Nevertheless, the difference in N uptake was insignificant between PM and PMB treatments. Also, there was no significant differences in N uptake among PM+50% N, PMB+50% N and 100% N treatments. Overall, the superiority of PM in enhancement of N uptake and yield of both crops may be associated with its large application rate (20 t h^{-1}) and higher content of nitrogen.

TABLE VI
TOTAL N RECOVERY AS APPLIED N FROM PM, PMB AND INORGANIC NITROGEN FERTILIZER

Treatments	Wheat					Forage sorghum				
	applied N kg h^{-1} from			Total applied N kg h^{-1}	N recovered %	applied N kg h^{-1} from			Total applied N kg h^{-1}	N recovered %
	PM	PMB	inorganic N fertilizer			PM	PMB	inorganic N fertilizer		
Control	0	0	0	0	------	0	0	0	0	------
100% N	0	0	285	285	17.30	0	0	238	238	27.64
PM+0% N	394	0	0	394	5.04	394	0	0	394	10.64
PMB+0% N	0	155	0	155	6.73	0	155	0	155	19.05
PM+25% N	394	0	72.25	466.25	6.59	394	0	59.5	453.5	11.00
PMB+25% N	0	155	72.25	227.25	7.55	0	155	59.5	214.5	21.00
PM+50% N	394	0	142.5	536.5	10.15	394	0	119	513	13.56
PMB+50% N	0	155	142.5	297.5	9.24	0	155	119	274	20.06
PM+75% N	394	0	214.75	608.75	12.21	394	0	178.5	572.5	15.59
PMB+75% N	0	155	214.75	369.75	12.28	0	155	178.5	333.5	25.59
PM+100% N	394	0	285	679	13.13	394	0	238	632	16.56
PMB+100% N	0	155	285	440	12.34	0	155	238	393	24.93
$L.S.D_{0.05}$	---	---	----	---	2.47	---	---	---	---	6.88

As the obtained data showed, improvements of soil physical properties, SOC, mineral N, DOC and DON caused by incorporation of PM and PMB into the investigated soil was the main reason behind nutrients availability specially nitrogen and reflected in N uptake and recovery. Many other investigators are in agreement with our results, where applying organic manures such as chicken manure, farmyard and green manures and PMB improved poor physical and chemical properties of sandy soil and increased shoot dry weight of wheat and N uptake under semi-arid subtropical environment in Pakistan [13]. Addition of PM at a rate of 20 t ha^{-1} or PMB at a rate of 10 t ha^{-1} in combination with inorganic N to sandy soil under arid conditions made significant changes in the soil C:N ratio, either by increasing or decreasing soil nitrogen and carbon contents. Driven by the need for both producing more food and lessening the environmental risks of intensive agriculture in newly reclaimed sandy soils. It could be concluded from these results that reducing soil nitrogen storage and increasing stabile carbon storage by biochar addition is the most feasible approach considering the current soil carbon and nitrogen situation (C/N ratio 9.50) in the investigated sandy soils under arid and semi-arid conditions. This will not only reduce the risk of declining carbon stability in these soils caused by the overuse of nitrogen fertilizers, but also will help to minimize nitrogen pollution risk and increase crop yield under such conditions.

IV. Conclusion

Under this field experiment, PM application at a rate of 20 t ha^{-1} or PMB at a rate of 10 t ha^{-1} in combination with inorganic N to sandy soil under arid conditions made significant improvements in soil physical, hydro-physical, SOC, mineral N, DOC, and DON and consequently reflected on increased wheat and fodder yield compared to individual N fertilizers. Moreover, applying biochar derived from PM or PM resulted in improvement of chemical properties of sandy soil, high uptake, agronomic and apparent recovery efficiency of applied N for both wheat and sorghum plants. It could be concluded that yearly applying of organic manures consisted of a labile carbon to sandy soils are always subject to high decomposition and mineralization rates, while one addition of PMB considered as a source of stabile carbon through cropping seasons. Therefore, under arid and semi-arid conditions, sustainable productivity in sandy soil reclamation projects desires frequently addition of such organic amendments or one addition of PMB. These results point to the feasibility of using biochar to improve fertility and productivity of sandy soils under arid and semi-arid conditions and emphasize the need to have more studies and focus on biochar life cycle after addition to sandy soils.

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