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Nitrogen Use Efficiency in Maize (*Zea mays* L.) as Affected by Different Organic Amendments

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ABSTRACT

Integrated nutrient management plays significant role in order to bringing sustainability in crop production. So, keeping in view this fact, a field experiment was conducted to check the impact of different fertilizer biochar (BC), poultry manure (PM) and nitrogen (levels) on the performance of spring maize (*Zea mays* L.) Experiment was conducted at Post Graduate Agriculture Research Station, University of Agriculture, Faisalabad (Pakistan, during the spring season 2013). Randomized complete block design with three replications, was used to conduct experiment. The treatments were Control to 10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N. Standard procedures for recording parameters related to yield and quality of maize were followed. Application of biochar increased yield grain information. Maximum grain yield (4.36 t ha^{-1}), biological yield (14.47 t ha^{-1}), number of grains per cob (304.7), 1000 grain weight (283 g) and grain protein contents (11.02%) were recorded in (T_{13}) where 250 kg ha^{-1} nitrogen + 10 t ha^{-1} biochar and 10 t ha^{-1} poultry manure were applied.

Key words: Maize, Nitrogen, Biochar, Poultry manure and yield.

INTRODUCTION

After wheat and rice, maize (*Zea mays* L.) is the third cereal crop in the world. In Pakistan, it provides raw material for agro allied-based [1]. It is also an important source of food for human beings, poultry and livestock [2]. In Pakistan, it is being cultivated on an area of 1.083 million hectares with average yield of 3.93 t ha^{-1} and annual grain production is 4.271 million tons [3]. It contributes 2.2% to the value added in agriculture and 0.5% to GDP [3]. In Pakistan, production of maize is very low due to various reasons. One of important reasons is inadequate nutrients supply [4]. Chemical fertilizers are most widely being used to fulfill the nutrients requirement of crops. But, the use of chemical fertilizers (especially nitrogenous fertilizers) is going to be most limiting factor due to increasing demand of farming community and unavailability at the time of need. The cost of these fertilizers is very high and farmers cannot afford the increase in price.

Maize is being used as staple food in many countries. It is highly nutritive crop as its grain comprises of 72% starch, 10% protein, 4.8% oil, 5.8% fiber, 3.0% sugars and 1.7% ash [5]. It shares a major contribution in farmer's economy of developing countries [6]. In advanced countries, about 90% of maize is used for making animal feed and other industrial products such as corn starch, corn oil, dextrose, corn syrup, corn flakes, cosmetics, waxes, alcohol and tanning material for leather industry.

Nitrogen promotes plant growth and enhances the crop yield [7, 8]. Responses of maize hybrids to nitrogen (N) fertilizers differ because of their different genetic ability to up-take, its utilization and translocate in their metabolism [9]. Nitrogen is the most important nutrient for maximum harvest of maize [10]. Application of nitrogen fertilizers is vital to optimize maize grain yield and also to improve physical grain quality.

Poultry manure (PM) can serve as a suitable alternate to chemical fertilizer as it is a valuable fertilizer. To increase the organic matter of the soil and provision of nutrients to crops are the main reasons for applying PM in agriculture [11]. Poultry manure is an excellent source of N, P, K and other essential nutrients [12]. Addition of poultry manure in the soil improves the soil structure, nutrient retention, aeration, soil water holding capacity and water infiltration. It is observed that poultry manure significantly increases the grain yield and harvest index of maize [13]. A strategy for soil C sequestration that has been recently gaining attention is the application of biochar to agricultural soils [14]. Biochar is a C-rich material formed bypyrolysis (heating) of biomass in an oxygen-limited environment [15]. Research has demonstrated that biochar has the potential to increase agricultural yields and long-term (hundreds to thousands of years) C storage in soils [14]. From the above discussion, it is much clear that urea, poultry manure and biochar have their significant role in provision of nutrients especially to the plants. This study is therefore, planned to assess the influence of different nitrogenous source and, biochar level to investigate the best possible combinations of biochar and inorganic fertilizers for hybrid maiz. The present study was conducted with following objective: To develop more economical and sustainable nutrient management approach for enhancing nitrogen use efficiency (NUE) in maize.

MATERIALS AND METHODS

The experiment was conducted on a sandy loam soil at the Research Area (PARS) of University of Agriculture, Faisalabad (Pakistan). The climate of the region is semi-arid and subtropical. The experimental area is located at 31° North latitude and 73°East longitudes with an altitude of 184 m on the globe. Soil of the experimental area was quite uniform, so a composite and representative soil sample to a depth of 30 cm was obtained by a soil auger prior to sowing of the crop. A soil sample was analyzed for its various physio-chemical properties (Table 1).

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Table 1. Soil Analysis

Chemical Analysis		
	Before Harvest	After Harvest
Ph	8.2	7.8
EC (dS m^{-1})	1.94	3.49
Nitrogen (%)	0.032	0.048
Phosphorus (ppm)	19.4	8.5
Potassium (ppm)	190	160
Organic Matter (%)	0.98	1.26
Mechanical Analysis		
Textural Class	Sandy loam	Sandy loam

Percentage of sand, silt and clay was determined by Bouyoucos hydrometer method using one percent sodium hexameter phosphate as a dispersing agent [16].Treatments were applied as Control (T_1) to10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N (T_{13}). Maize hybrid DKC-6142 was sown in the 1st week of March, 2013. Sowing was done with hand drill by using seed rate of 25 kg ha^{-1} in 75 cm apart rows. Biochar and poultry manure were applied at soaking irrigation. Nitrogen was applied according to treatments. Phosphorus and Potassium were applied at the rate of 125 kg ha^{-1} and 125 kg ha^{-1} respectively. Nitrogen (from urea) was applied in three splits (at sowing, knee height and flowering). While DAP and SOP was applied as a source of P and K, respectively at the time of sowing.

Statistical Analysis:

The data were analyzed statistically using the Fisher's analysis of variance. Least significant difference (LSD) test at 5% probability level was used to compare the differences among treatments' means when F-value is significant for observations [17] .

RESULTS AND DISSCUSION

Number of grains per cob

Maximum number of grains per cob (304.7) was observed in T_{13} (10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N) while minimum number of grains per cob (174.3) was observed where control (T_1) was applied. The increase in number of grains per cob is might be due the improvement in the CEC of the soil, a decrease in the hydraulic conductivity of the soil and an increase in the carbon, nitrogen and phosphorus content of the soil. However, significant effect of nitrogen sources on number of grains per cob is against the findings of [18]. Similar results are reported by [19]who reported that biochar is a porous material with high surface area thus it can significantly affect soil moisture and nutrient dynamics and yield characteristics like number of grains per cob and grain yield of corn.

1000-grain weight (g)

Maximum 1000-grain weight (283 g) was observed in T_{13} (10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N) while minimum 1000-grains weight (205.7 g) was observed where control (T_1) was applied. The lower N level in the soil results in lighter grain weight due to less available N for the optimum plant growth [20] and formation of assimilates for healthy grains. Organic amendment in the soil (incorporation of biochar and PM) have thought to reduce the evaporation demand, reduces the N_2 losses, thus have adequate water and nitrogen for plant root growth, or perhaps due to the softness of soil caused by organic amendments (because biochar has high surface area) in which the roots may expand rapidly enough into wet soil to meet crop water and nutrient requirements. Our results are also confirmed by the findings of [21] who observed that integrated N strategies convincingly enhance corn yield attributes. Similar findings were shared by [21]. However, our results of 1000-grains weight are against the findings of [22] and [18].

Biological yield (t ha^{-1})

Maximum biological yield (14.47 t ha^{-1}) was observed in T_{13} (10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N) while minimum biological yield (8.21 t ha^{-1}) was observed where control (T_1) was applied. The increase in biological yield of maize in integrated N may be due the slow release and timely availability of nitrogen from biochar which were less subjected to lose as compared to mineral N applied (alone) which loss from soil more rapidly. Similar results were reported by [23] who noted that application of biochar had significant effect on maize biomass production and increased maize yield by 32% as compared to control. These results are in line with [24] who reported maize biological yield can be increased by improving fertilizer use efficiency and cultural practices. However, these results are against the findings of [18] who found non-significant increase in biological yield of maize with application different nitrogen levels with organic amendments.

Grain yield (t ha^{-1})

Maximum grain yield (4.36 t ha^{-1}) was observed in T_{13} (10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N) and minimum grain yield (1.62 t ha^{-1}) was observed where control (T_1) was applied. Possible explanation for increase in grain yield is due to increase in cob length, 1000 grain weight in biochar amendments plots, including the effect of biochar on soil physio-chemical properties of soil and providing a medium for adsorption of plant nutrients and improved conditions for soil micro-organisms [25]. Biochar efficiently adsorbs ammonia (NH_3) [26] and acts as a binder for ammonia in soil, therefore having the potential to decrease ammonia volatilization from soil surfaces. These results are in accordance with [27] who suggested that timely availability of N could be insured and corn productivity can be positively increased by combined use of mineral N and Organic manures.

Grain protein contents (%)

Maximum grain protein contents (11.02%) were observed in T_{13} (10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N) and minimum grain protein contents (8%) was observed where control (T_1) was applied. Fertilization with nitrogen significantly increased grain yield and protein contents in maize. It has been studied that use of different levels of nitrogen (60, 120 and 180 kg N ha^{-1}) to seven maize hybrids displayed a positive association between high grain yield and nitrogen rates and maximum grain yield was obtained by applying 120 kg N ha^{-1}. Protein contents increased from 4.60 to 11.2 % with N application of 60 to 180 kg N ha^{-1} respectively [28]. The reason of increase in protein content is the availability of nitrogen during grain development by biochar, PM and N from Urea. Integrated nutrition also increased the protein content as compare to synthetic fertilizer alone. NUE and physiological efficiency decreased with increasing N levels. Nitrogen addition as urea showed a favorable significant effect in improving most studied traits than ammonium nitrate. The fertilizer N uptake showed that urea was a more available source of N for maize than ammonium nitrate. The maximum grain protein contents (%) were achieved by 214 kg N ha^{-1} as urea with Sakha-94 [18]. Similar results have been reported by [29, 30, 31, 32]

Table 2.Effects of nitrogen with different organic amendments on 1000-grain weight (g), biological yield (t ha-1), grain yield (t ha-1), Number of grains per cob and protein content of maize (Zea mays L.)

Treatment	**1000-GW (g)**	**BY (t ha^{-1})**	**GY (t ha^{-1})**	**NGC**	**GPC (%)**
T_1 : Control	205.70 j	8.20 l	1.62 l	174.30 l	8.00 m
T_2 : 8 t ha^{-1} PM + 150 kg ha^{-1} N	219.00 i	9.22 k	1.90 k	183.10 k	8.09 l
T_3 : 8 t ha^{-1} PM + 250 kg ha^{-1} N	245.70 de	11.80 f	2.63 f	228.10 f	9.21 f
T_4 : 10 t ha^{-1} PM+150kg ha^{-1} N	224.30 hi	9.73 j	2.05 j	193.30 j	8.13 k
T_5 : 10 t ha^{-1} PM + 250 kg ha^{-1} N	251.70 cd	12.52 e	2.90 e	238.00 e	9.71 e
T_6 : 5 t ha^{-1} BC + 8 t ha^{-1} PM + 150 kg ha^{-1} N	227.00 ghi	10.27 i	2.08 j	197.00 i	8.21 j
T_7 : 5 t ha^{-1} BC + 8 t ha^{-1} PM + 250 kg ha^{-1} N	257.70 c	13.10 d	3.12 d	246.00 d	10.00 d
T_8 : 5 t ha^{-1} BC + 10 t ha^{-1} PM + 150 kg ha^{-1} N	231.30 gh	10.70 h	2.21 i	199.30 i	8.31 i
T_9 : 5 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N	259.30 c	13.53 c	3.31 c	260.40 c	10.37 c
T_{10} : 10 t ha^{-1} BC + 8 t ha^{-1} PM + 150 kg ha^{-1} N	235.00 fg	11.02 g	2.39 h	209.20 h	8.67 h
T_{11} : 10 t ha^{-1} BC + 8 t ha^{-1} PM + 250 kg ha^{-1} N	270.00 b	13.74 b	3.70 b	279.10 b	10.77 b
T_{12} : 10 t ha^{-1} BC + 10 t ha^{-1} PM + 150 kg ha^{-1} N	241.70 ef	11.63 f	2.58 g	219.20 g	9.01 g
T_{13} : 10 t ha^{-1} BC + 10 t ha^{-1} PM + 250 kg ha^{-1} N	283.00 a	14.47 a	4.36 a	304.70 a	11.02 a
LSD value at 5%	**8.63**	**0.199**	**0.035**	**2.982**	**0.019**

CONCLUSION

It is concluded that effects of nitrogen with different organic amendments on maize (hybrid DKC 6142) grain yield information was significant. Maximum grain yield (4.36 t ha-1), biological yield (14.47 t ha^{-1})' number of grains per cob (304.7) 1000 grain weight (283 g) and grain protein contents (11.02%) were recorded in treatment (T13) where 250 kg ha-1 nitrogen + 10 t ha^{-1} biochar and 10 t ha^{-1} poultry manure were applied.

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