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Role of Organic Amendments and Micronutrients in Maize (*Zea mays* L.) Sown on Calcareous Soils

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Abstract: Micronutrients status and organic matter are two main contributing factors in soil productivity. Unfortunately, our soils are deficient in both of them. Addition of poultry manure and humic acid along with application of micronutrients can recover their deficiency efficiently. So, keeping in view this fact, a field experiment was conducted to check the role of organic amendments and micronutrients in spring planted maize (*Zea mays* L.). Experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad during the spring season 2014. Randomized complete block design with three replications was used to conduct the experiment. Plot size was 6 m × 3 m with row to row distance of 75 cm having plant to plant distance 25 cm. The treatments were, control, poultry Manure (PM) @ 8 ton ha^{-1}, Humic Acid (HA) @ 15 kg ha^{-1}, Micronutrients (MN including Zn, Fe, Cu and Mn) @ 6.25 kg ha^{-1} each, PM + HA, PM + MN, HA + MN, PM + HA + MN. Standard procedures for recording parameters related to yield and quality of maize were followed. The maximum plant height at maturity (218.67 cm), ear length (20.47 cm), number of grains per ear (372), 1000-grain weight (260.33 g), biological yield (18.58 t ha^{-1}), grain yield (7.35 t ha^{-1}), harvest index (39.56) and grain protein contents (9.64%) were recorded where 8 t ha^{-1} Poultry Manure + 15 kg ha^{-1} Humic Acid + 6.25 kg ha^{-1} Micronutrient (Zn, Fe, Cu, Mn) were applied. So, it can be concluded that 8 t ha^{-1} Poultry Manure + 15 kg ha^{-1} Humic Acid + 6.25 kg ha^{-1} Micronutrient (Zn, Fe, Cu, Mn) would be an efficient nutrient management strategy for farming community in order to enhance maize production on sustainable basis.

Key words: Maize · Poultry manure · Humic acid · Zn · Fe · Cu · Mn

INTRODUCTION

Maize is the third most important cereal crop in the world after wheat and rice. It provides raw materials for agriculture based industries in Pakistan [1]. It remains as better source of nourishment for human beings, poultry, animals and livestock [2] and is placed among the cash crops for growers living around the cities [3]. It is cultivated on an area of 1117 thousand hectares with the annual grain production of 4527 thousand tons in Pakistan [4]. The soils in our country have generally low potential due to wrong management practices and poor nutrition of the crops. Organic matter is usually below 1% in our soils and chemical fertilizers consume a large amount of energy for manufacturing [5]. Some other drawbacks in their use are low supply, less availability at the time of need, adulteration and high cost of production. While, continuous use of synthetic fertilizers is also polluting the environment rapidly [6].

Soil fertility can be increased by balanced fertilization *via* both minerals as well organic amendments [7]. Recently the combined use of organic and chemical fertilizers has boosted maize and other cereals' yields [8]. From organic point of view, poultry manure (PM) and humic acid (HA) are the better organic manures that can be incorporated into the soil to avoid the nutrient depletion on sustained basis as both are rich in nutrient supply and eco-friendly too. While application of Zn, Fe, Cu and Mn to the soil in sulphate form ($ZnSO_4$, $FeSO_4$, $CuSO_4$, $MnSO_4$) can recover the micronutrient deficiency efficiently.

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Poultry manure (PM) is an excellent source of N, P, K and other essential nutrients. Poultry manure has also been proven that it needs lesser N-fortification to produce more yield of maize than FYM [9]. Among all the available manures poultry manure is generally considered the best due to its higher decomposition rate and timely availability of plant nutrients. It supplements soil with organic matter which improves aeration, soil structure, nutrient retention, water holding capacity and soil water infiltration [10]. Poultry manure also gives better results in maize production by increasing leaf area, dry matter contents and grain yield [11]. Humic acid improves physical, chemical and biological characteristics of the soil. Physically, it improves soil porosity, structure and water holding capacity. Chemically, it increases soil retention and adsorption of inorganic plant nutrients. Biologically, it improves biological activities in the soil. Nutritionally, it is a source of nitrogen phosphorus and sulfur for plants [12]. Humic acid is a stable product obtained by the decomposition of organic matter that enhance crop growth by chelating the nutrients and also resists changes in soil pH [13]. Like macronutrients, micronutrients also play significant role in crop production [14]. However they are required in small amount and they work as cofactor in many of the metabolic processes in crops sown on calcareous soils. $ZnSO_4$ is the part of more than 300 enzymes in plant life and is utilized in protein making and the stability of DNA and RNA [15]. M. Maqsood, *et al.,* [16] studied the role of micronutrients (Fe, Cu, Zn and Mn) in maize and resulted that iron, copper, zinc sulphate and manganese sulphate had a combined effect and increased the number of ears, no of grains per ear, grain weight and grain yield and the micronutrients showed synergistic effect as well.

MATERIALS AND METHODS

The experiment was conducted on a sandy loam soil at the Agronomic Research Area, University of Agriculture; Faisalabad (Pakistan), during spring 2014. 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 are given below.

Table (….): Physio-chemical properties of soil site

	Chemical Analysis	
	Before Sowing	After Harvest
pH	7.9	7.6
EC (dS m^{-1})	1.70	1.74
Nitrogen (%)	0.50	0.54
Phosphorus (ppm)	5.40	5.75
Potassium (ppm)	170	175
Organic Matter (%)	0.98	1.26
Physical Analysis		
Textural Class	Sandy clay loam	Sandy clay loam

The treatments included application of poultry manure (PM), humic acid (HA) and micronutrients (MN) either single on in combination form i.e. control, poultry Manure @ 8 ton ha^{-1}, Humic Acid @ 15 kg ha^{-1}, Micronutrients (Zn, Fe, Cu and Mn applied in sulphate form) @ 6.25 kg ha^{-1} each, Poultry Manure + Humic Acid, Poultry Manure + Micronutrients, Humic Acid + Micronutrients, Poultry manure + Humic acid + Micronutrients.

Maize hybrid (Yousaf wala) was sown on 23rd of February, 2014 on ridges by choppa method (manual dibbling) on 75 cm apart rows using seed rate of 25 kg ha^{-1}. All treatments were applied at the time of sowing except humic acid that was split into three equal doses. Recommended dose of NPK (250: 125: 125 kg ha^{-1} respectively) was applied. Urea (as a source of N) was applied in three splits (at sowing, knee height and flowering), while single superphosphate (SSP) and sulphate of potash (SOP) were applied as a source of P and K, respectively at the time of sowing. All other agronomic practices were kept normal and uniform for all the treatments.

At the end of the growth period, different parameters (plant height, ear length, number of grains per ear, 1000-grain weight, biological yield, grain yield, seed protein content and economic analysis) were studied using standard procedure. The data was analyzed by using Fisher's analysis of variance technique and the difference among the treatment means were compared by employing LSD at 5% probability. Formulas used for different parameters as follow:

Harvest Index (%)

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological Yield}} \times 100$$

Grain Protein Contents (%)

Protein content = N %× 6.25

Net Return

Net Benefit (Rs. ha^{-1}) = Gross benefit - Total cost

Benefit Cost Ratio

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

RESULTS AND DISCUSSION

Plant Height at Maturity (cm): The comparison of individual treatment means (Table 1) indicates that maximum plant height (218.67 cm) was observed in T_7 (8 t ha^{-1} Poultry Manure + 15 kg ha^{-1} Humic Acid + 6.25 kg ha^{-1} Micronutrient (Zn, Fe, Cu, Mn each) while, minimum plant height (189.93 cm) was observed in T_0 (control).

Increase in plant height was mainly due to the more availability of all the nutrients from poultry manure, humic acid and the micronutrients ($ZnSO_4$, $FeSO_4$, $CuSO_4$, $MnSO_4$) throughout the growing season. Timely availability of nutrients mainly nitrogen from NPK as well as organic sources (PM and HA), rapid and better mineralization rate might have increased the dry matter accumulation and better crop growth that has positively changed the physiological functions of maize. These physiological processes tend to plays its role in cell division, cell expansion and enlargement and ultimately affect the overall vegetative growth of maize. $ZnSO_4$, $MnSO_4$ and other micronutrients made up for the micronutrient deficiencies especially that of zinc which is more prevalent among all micronutrient deficiencies.

Ear Length (cm): In maize, ear length is imperative yield contributing parameter because it influences the number of grains per ear, grain size and subsequently to grain yield. Results regarding the ear length (cm) of maize as affected by integrated organic amendments and micronutrients are shown in Table 1. Comparison of individual treatment means (Table 1) shows that maximum ear length (20.47 cm) was observed in T_7(8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each) While, minimum ear length (12.80 cm) was observed where T_0 (control) was applied.

Poultry manure and humic acid are not as effective in separate application as compared to the combine one because poultry manure requires some time to decompose, while humic acid is far better in giving quick response. Such results were possibly due to the more production and transfer of assimilates in ear on account of improved supply of nutrients. Similar results were reported by A.P. Maerere, [17].

Number of Grains per Ear: Comparison of individual treatment means (Table 1) reflects that maximum number of grains per ear (372.00) was observed in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each) yet it was statistically at par with treatment T_6 where the number of grains per ear were recorded 364.33. However, minimum number of grains per ear (210.33) was observed in T_0 (control).

The maximum number of grains per ear in experimental area, treated with T_7 treatment might be due to proper ear development (ear diameter and length) on account of more N supply from poultry manure along with recommended fertilizer [18]. Perhaps better silking and pollination tied with no photosynthetic stress on adequate supply macro and micronutrients might have steered to these results [19]. In general, humic acid application creates a favorable environment for plant and root growth especially by promoting a porous soil structure for optimized root penetration and decrease soil erodibility due to the formation of stable aggregates which ultimately contribute in the development of yield contributing parameters of maize [20]. Similar results were disclosed by M.A. Cheema, *et al.* [21].

1000-grain Weight (g): 1000-grain weight is an important yield contributing factor that can be estimates the grain yield of any crop. Data regarding1000-grain weight as affected by integrated organic amendments and micronutrients are shown in Table 1. Comparison of individual treatment means (Table 1) indicates that maximum 1000-grain weight (260.33 g) was observed in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each) yet it was statistically at par with T_6 where the observed 1000-grain weight was 248.00 (g). And minimum 1000-grain weight 186.67 (g) was observed in T_0 (control).

It might be due to the reason that on one hand PM is an excellent source of N, P and K and on the other hand humic acid minimize nutrient leaching which plays its role to increase the soil texture and biochemical activities to facilitate the availability of nutrients in early as well as on later stages of growth. Humic acid also functions as chelating agent for many of the unavailable nutrients. Hence, continuous supply of nutrients is available for healthy cobs. Different levels of organic and inorganic

Table 1: Effects of organic amendments and micronutrients on plant height at maturity (cm), ear length (cm), number of grains per ear, 1000-grain weight (g), biological yield (t ha^{-1}), grain yield (t ha^{-1}), harvest index and grain protein contents (%) of maize (*Zea mays* L.)

Treatments	Plant height at maturity (cm)	Ear length (cm)	Number of grains per ear	1000-grain weight (g)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index	Grain protein contents (%)
T_0 (Control)	189.93 e	12.80 d	210.33 f	186.67 f	10.21 e	2.13 e	21.00 d	5.40 g
T_1 (PM)	199.63 d	16.87 c	334.33 e	206.00 ef	16.07 d	5.11 d	31.74 c	6.73 f
T_2 (HA)	204.80 cd	16.90 c	345.33 d	212.50 de	16.17 cd	5.51 cd	34.07 bc	7.77 e
T_3 (MN)	209.27bc	17.80 bc	357.33 bc	226.67 cd	17.04 bcd	5.78 c	33.90 c	8.58 cd
T_4 (PM + HA)	206.47 bcd	17.20 bc	347.33 cd	223.33 de	17.02 bcd	5.62 cd	33.13 c	8.45 d
T_5 (PM + MN)	212.13 abc	18.13 b	361.67 bc	240.67 bc	17.26 bc	6.50 b	37.68 ab	8.83 bc
T_6 (HA + MN)	213.33 ab	18.37 b	364.33 ab	248.00 ab	17.41 b	6.60 b	37.93 a	8.96 b
T_7 (PM + HA + MN)	218.67 a	20.47 a	372.00 a	260.33 a	18.58 a	7.35 a	39.56 a	9.64 a
LSD	7.433	1.217	9.634	19.47	1.101	0.5286	3.625	0.2633

Any two means not sharing same letter differ significantly at 5% probability level (LSD)

PM = 8 tonn ha^{-1}, HA = 15 kg ha^{-1}, MN = 6.25 kg ha^{-1} Micronutrients (Zn, Fe, Cu and Mn each)

fertilizers significantly affected the 1000-grain weight of maize that got enhanced [22] W.D. Kong, *et al.* [23] also observed linear increase in 1000-grain weight by increasing levels of $ZnSO_4$ and $MnSO_4$.

Biological Yield (t ha-1): Individual treatment means (Table 1) indicated that the maximum biological yield (18.58 t ha-1) was observed in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each), while, the minimum biological yield (10.21 t ha-1) was observed where control (T_0)was applied.

Consistent supply of NPK along with trace elements promotes plant growth and enhances the crop yield [24]. The reason of increase in biological yield with T_5 treatment is due to increase in plant dry weight and allocating more dry matter to vegetative organs as well. This might be due to slow nutrient releasing nature of poultry manure [25]. Moreover, due to larger residual effect of poultry manure, nutrient recovery efficiency is higher [26].

Grain Yield (t ha-1): Comparison of individual treatment means (Table 1) shows that the maximum grain yield (7.35 t ha-1) was observed in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each),while the minimum grain yield (2.13 t ha-1) was observed in T_0 (control).

Possible explanation for increasing grain yield might be due to increase in ear length, 1000 grain weight with the same treatment (T_7) including the effect of humic acid on soil physio-chemical properties of soil and providing a medium for adsorption of plant nutrients and improved conditions for soil micro-organisms. Along with humic acid, poultry manure contributed towards the yield and yield parameters by slow release of macronutrients to the plants to ensure their continuous supply otherwise they might have been fixed in clays or washed out in erosion, moreover, keeping the soil in better aggregates. Micronutrients especially zinc that is more deficient contributed toward more yield in the applied treatments. The observations are also supported by the experimentation of Jose, M. Alvarez and D. Gonzalez, K.G. Roberts, *et al.* [27, 28].

Harvest Index (%): The physiological efficiency of crop to portioning the dry matter into its economic yield is termed as its harvest index (HI). It indicates the ability of a plant to proportionate the plant assimilates into grain and other vegetative parts of plants. Comparison of individual treatment means (Table 1) indicates that the maximum harvest index (39.56%) was recorded in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each), while, the minimum harvest index (21.00%) was observed in T_0 (control).

Sustainable increase in harvest index might be due to enhanced water-holding Synergisms, developed between applied inorganic fertilizers, PM and humic acid which ultimately caused a higher nutrient retention/availability (by reducing percolation/leaching losses) and enhanced NUE [29]. It has been also reported that although humic acid did not provide a significant source of plant nutrients yet it could improve the efficiency of inorganic synthetic fertilizers [30, 31].

Grain Protein Contents (%): Individual treatment means (Table 1) indicated that the maximum grain protein contents (9.64%) were observed in T_7 (8 t ha-1 Poultry Manure + 15 kg ha-1 Humic Acid + 6.25 kg ha-1 Micronutrient (Zn, Fe, Cu, Mn each) and the minimum grain protein contents (5.40%) was observed where T_0 (control) was applied.

Table 2: Impact of organic amendments and micronutrients on net return (Rs. ha^{-1}) and BCR of maize (*Zea mays* L.)

Treatment	Grain Yield (t ha^{-1})	Value (Rs. ha^{1})	Straw yield (tha^{1})	Value (Rs. ha^{1})	Gross income (Rs. ha^{-1})	Total cost (Rs. ha^{1})	Net return (Rs. ha^{-1})	BCR
T_0 (Control)	2.13	63900	8.080	24240	88140	61200	26940	1.44
T_1 (PM)	5.11	153300	10.96	32890	186190	128560	57630	1.45
T_2 (HA)	5.51	165200	10.66	31980	197180	122060	75120	1.62
T_3 (MN)	5.78	173400	11.26	33790	207190	131060	76130	1.58
T_4 (PM + HA)	5.62	168700	11.39	34180	202880	130060	72820	1.56
T_5 (PM + MN)	6.50	194900	10.76	32280	227180	139060	88120	1.63
T_6 (HA + MN)	6.60	197900	10.82	32460	230360	132560	97800	1.74
T_7 (PM + HA + MN)	7.35	220400	11.23	33700	254100	140560	113540	1.81

PM = 8 tonn ha^{-1}, HA = 15 kg ha^{-1}, MN = 6.25 kg ha^{-1} Micronutrients (Zn, Fe, Cu and Mn each)

Nitrogen is an integral part of protein. Nitrogen has paramount effect in the synthesis of protein in the grains of maize [32]. The quality of maize grain improved with the application of PM which resulted in increase in grain protein contents. Integrated application of N from NPK, PM and humic acid ultimately increased N supply. This increase could be due to the reason that PM is generally more concentrated in nutrients and narrow in C:N [33]. The increase of N supply resulted in formation of N containing protein, which competed strongly for the fat synthesis.

Economic Analysis: Different treatments of poultry manure, humic acid and micronutrients resulted in different net income (Rs. ha^{-1}) and benefit cost ratio (Table 2). Data regarding economic analysis presented in Table 2 revealed that treatment T_7 resulted in highest net income and the highest benefit cost ratio (1.81) while treatment T_0 resulted in the lowest benefit cost ratio (1.44).

CONCLUSION

It can be concluded that application of poultry manure, Humic Acid and micronutrient (Zn, Fe, Cu, Mn each) in combination would be an economical strategy for farming community in order to enhance maize production on sustainable basis.

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