Research Article

Maize Growth in Response to Beneficial Microbes, Humic Acid and Farmyard Manure Application

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Abstract | The useful and safe disposal of farmyard manure (FYM) is required for avoiding the environmental pollution. However, the bulky application of FYM and slow decomposition limits its widespread application by farmers as a source of nutrients. With the objectives of improving soil mineral N availability and its impact on maize growth, two years field experiments were conducted at the University of Agriculture Peshawar in 2017 and 2018. The experiment included three factors i.e. beneficial microbe (BM: 25 and 50 L ha^{-1}) as effective microbes, humic acid (HA: 3, 6 and 9 kg ha^{-1}) and FYM (10, 15, 20 Mg ha^{-1}) obtained from cattle dung, urine and leftover organic materials along with a control (No- BM, HA or FYM). The required quantity of BM solution (mixed with 1 L of distilled water for each plot) was sprayed on soil surface having HA (applied as mixture with 1 kg soil for each plot) and FYM (soil incorporated with rotavator) one month before sowing. Maize growth contributing parameters (leaves $plant^{-1}$, leaf area and index, ear length, and plant height) were improved in treated plots than control plots. The application of 50 L BM ha^{-1} improved maize growth contributing parameters over 25 L BM ha^{-1}. Increasing the application rate of HA from 3 to 9 kg ha^{-1} had increased leaves $plant^{-1}$, leaf area, leaf area index, plant height and ear length of maize. Higher application of FYM had improved the maize growth parameters. Mineral nitrogen contents were positively correlated with leaves $plant^{-1}$, leaf area, leaf area index and plant height as well as grain yield of maize. It was concluded that FYM mineralization increased with addition of either 50 L BM ha^{-1} or 6-9 kg HA ha^{-1}, which improved the maize growth contributing parameters as well as soil nitrogen status. Thus, 20 Mg FYM ha^{-1} should be applied in combination with 50 L BM ha^{-1} and/or 6 kg HA ha^{-1} for improving the mineral N availability and maize productivity.

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Introduction

Maize (*Zea mays* L.) is a cereal crop grown in almost all countries of the world. It has largely used as a staple food in Pakistan as well as other developing countries of the world. In Khyber Pakhtunkhwa, it is the 2nd most important and grown crop after wheat (*Triticum aestivum* L.), whereas in Pakistan its rank is 3rd. Maize crop has multiple uses like it is used as food, feed and raw materials for commercial product preparation (Khan *et al*., 2017). Pakistan economic survey show that maize was planted on 1.40 million ha land and produced 7.88 million tons with 5121 kg ha^{-1} average yield (MNSF&R, 2020). In Pakistan, maize production is lower than world leading countries due to less fertility of soil, improper usage and time of fertilizer application and several other agronomic management problems. Maize is an exhaustive crop and required high amount of nitrogenous fertilizer compared to other cereal crops. Thus, soil conditioners like beneficial microbes (BM) and humic acid (HA) were utilized to decompose the added farmyard manure for nutrients availability and its impact on maize growth.

Farmyard manure (FYM) consist of animal waste products and leftover materials of farm that contains plants nutrients (Satyanarayana *et al*., 2002). According to an estimate of Bhattacharyya *et al*. (2007), the FYM production in the world and in Pakistan are up to 7 billion tons and 3.30 million tons, respectively. Huge stock of FYM could create environmental issues (Jiang and Yan, 2010), and its safe disposal is needed. FYM recycling for obtaining nutrients in farming system is widely practiced by the farmer specifically in developing countries (Khan *et al*., 2017; Khan *et al*., 2019). However, the bulky nature and high quantity requirements has minimized its usage as nutrient source (Muhammad *et al*., 2018) in agroecosystem. Similarly, the FYM decomposition is slow and time-consuming process for plant's nutrients availability. Improving the nutrient release from FYM with the help of soil amendments can be considered as essential research question in soil having low soil organic matter.

Organic fertilizers like FYM is a good source of available nutrients for plant growth and production (Khan *et al*., 2015). Farmyard manure increases soil organic matter, soil health and fertility, microbiological activities (Bello *et al*., 2020), soil structure enhancement for sustainable agriculture (Luo *et al*., 2018), crop development and yield (Khan *et al*., 2017). The beneficial microorganisms (BM) are mixed cultured microbes used as inoculants for improving the microbial diversity, increase soil health and nutrients availability, thus increased crop development and yield (Azeem and Ullah, 2016). Crop production enhances by bacterial inoculation through bacterial nitrogen fixation, uptake nutrients by solubilization, hormonal activities and increases available nutrients. Similarly, humic acid (HA) consisted of mostly carbon products found in lignite coal of Pakistan (Hai and Mir, 1998). Humic acid are associated to soil biological, physical and chemical characteristics (Khattak and Muhammad, 2008). Humic acid enhances biological and physico-chemical properties of soil. Model humic acid polymer are combination of organic carbon (51-57%), total nitrogen (0.70-1.65%) and phosphorus (0.25-0.94%) (Brannon and Sommers, 1985). Beneficial microbes and humic acid combine with organic/inorganic fertilizers enhances accessibility of nutrients (Hussain *et al*., 1999). Humic acid acts chelating agent to boost the nutrients availability as well as to maintain soil nutrients condition. Humic acid combine with fertilizers can enhance crop growth, development and production (Bharali *et al*., 2017). Beneficial microorganisms associated with organic fertilizers enhances plant growth, crop yield and soil quality (Haji *et al*., 2014). Application of beneficial microorganism to soil enhances atmospheric nitrogen fixation, perishing organic residues and waste materials delivering important nutrients availability through nutrient cycling for plant growth, detoxifying pesticides, vanquishing of pathogens/diseases, increasing bioactive compounds (Kurepin *et al*., 2014).

Low soil organic matter (< 1) of the study area could not maintain maize production in continuous cropping system (Ibrahim *et al*., 2020). Similarly, application of chemical fertilizer possibly enhanced crop yield (Khan *et al*., 2018), however its application is less profitable and hazardous to environment (Muhammad *et al*., 2018) as most of nitrogen is lost into environment either as nitrate polluting water bodies or ammonium. Hence, application of BM with organic fertilizers will decompose manure and enhance nutrient availability and will be more economical (Haji *et al*., 2014). Similarly, HA as a soil conditioner, enhance the soil richness and hence crop yield (Bharali *et al*., 2017). Presently, maintaining the standard of quality and quantity of agricultural commodities is the need of the day, which is only possible by utilizing organic manures for safe food, better ecosystem, minimum cost of cultivation, clean environment for better human health (Khan *et al*., 2018). Therefore, this research was initiated to find out the effect of BM and HA application as soil conditioner on FYM decomposition and its impact on maize growth contributing parameters.

Materials and Methods

Experimental site

Experiment was carried out at Agronomy Research Farm, The University of Agriculture in summer of 2017 and 2018. The studies were conducted to optimize beneficial microbes (BM) as effective microbes from bioaab, humic acid (HA) as soil conditioner and farmyard manure (FYM) as leftover material from

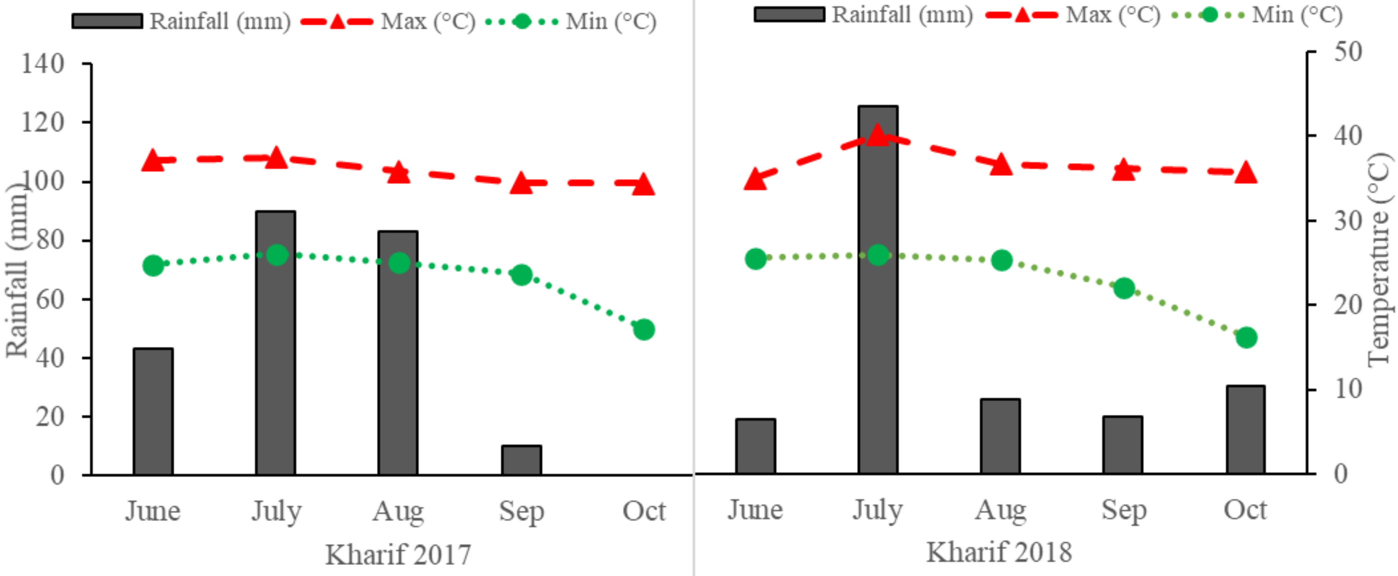

Figure 1: *Rainfall (mm), temperature maximum (Max ˚C) and minimum (Min ˚C) of the study area during 2017 and 2018.*

Table 1: *Physico-chemical properties of soil, farmyard manure (FYM) and humic acid.*

Physico-chemical properties	Unit	Soil	FYM	Humic acid
Organic matter	%	0.53	15.8	51.63
Total nitrogen	g kg^{-1}	0.03	0.86	2.26
Mineral nitrogen	mg kg^{-1}	0.68	-	
pH	-	8.1	6.9	7.21
Electrical conductivity	dS m^{-1}	0.41	3.7	2.13
Phosphorous*	mg kg^{-1}	3.87	0.26%	4.54%
Potassium*	mg kg^{-1}	112	0.71%	7.32%
Bulk density	g cm^{-3}	1.23	-	-
Sand	%	20.16	-	-
Silt	%	70.21	-	-
Clay	%	9.63	-	-
Textural class	-	Silt loam	-	-

** In soil EDTA extractable*

cattle farm for improving maize growth parameters. The soil properties of the experimental field were investigated before sowing in 2017 using standard protocols (detailed below). The research field soil was silty loam with sand (20.16%), silt (70.21%) and clay (9.63%), and classified as Ustochrept (Anonymous, 2007), and detailed in Table 1. The soil of the experimental site was alkaline with pH (8.1), SOC (0.53%), total N (0.03%), mineral N (0.68 mg kg^{-1} soil), electrical conductivity (0.41 dS m^{-1}), EDTA extractable P (3.87 mg kg^{-1}), EDTA extractable K (112 mg kg^{-1}) and soil bulk density (1.23 g cm^{-3}). During last five years, the experimental plots were sown with maize in summer and wheat in winter seasons with a regular maize-wheat-maize cropping pattern. The climatic data on temperature and rainfall collected in the study area is provided in Figure 1.

Materials and treatments

The experiment was conducted in RCB design with three replications. Three factors *i.e.* beneficial microbes (BM), humic acid (HA) and farmyard manure (FYM) along with a control were used in the studies. The BM was applied as 25 or 50 L ha^{-1}, HA as 3, 6 or 9 kg ha^{-1} and FYM as 10, 15 or 20 Mg ha^{-1}. The properties of FYM collected from the Dairy Farm of the University is given in Table 1. The analysis indicated that FYM contain OC (15.80%), total nitrogen (0.86%), pH (6.9), electrical conductivity (3.7 dS m^{-1}), EDTA extractable P (0.26 %) and EDTA extractable K (0.71%). The humic acid was applied as "humic plus-40%" a commercial product of Al-Hameed Chemicals Pvt limited and containing OC (51.63%), total nitrogen (2.26%), pH (7.21), electrical conductivity (2.13 dS m^{-1}), EDTA extractable P (4.54 %) and EDTA extractable K (7.32%). The application of beneficial microbes were made from "Bioabb" (as effective microbial solution) a commercial product manufactured by NFRDF-NGO in association with The University of Faisalabad-Pakistan, and consisted of *Lactobacillus bacteruim, Rhodopseudomona sp, Actinomycetes, Cyanobacteria, Saccharomyces sp.* (yeast) and molasses as media.

Preparation of treatments and its application

The experimental plots of 4×4.5 m dimension were prepared and separated with small bund (5-7 cm high). The FYM was added to the soil as per proposed rates on dry weight basis, whereas the humic acid was applied to the soil as a mixture of proposed rate with one kg soil to each plot. The proposed rates of BM as 2% solution was mixed with one liter of distilled water, well shaken, and sprayed as saturated liquid on the soil, where FYM and HA were already applied. After application of the treatments, plots were ploughed single time with common field cultivator to incorporate all these materials of the treatments to a depth of 15 cm. The application of BM, FYM and HA was carried out about one month before sowing each year. A total of two irrigation, 1st after 10 days and 2nd after 20 days of treatment incorporation was provided for proper and effective decomposition of treatment and to maintain plots at proper field capacity level before sowing.

Field operations and methodology

One month after treatment imposition, the field was ploughed two times using common field cultivator at proper field capacity level in each year. The field cultivator was followed by rotavator in the respective plots for proper seed bed preparation. The plots were rebuilt and separated with 10-15 cm high and 30 cm wide bunds between two plots. However, the replication-to-replication distance was 1 m. Maize (cv. Azam) was sown at the seed rate of 30 kg ha^{-1} in plots of 18 m^2 having 6 rows of 4 m length and spaced 75 cm. The sowing of maize was made on July 8, 2017 for the first year and July 7, 2018 for the 2nd year on the same plots with same treatment procedure. However, general wheat was grown between two maize crops and provided with recommended amount of 120 kg N ha^{-1} and 90 kg P ha^{-1} as a gap crop. The wheat was planted in 2nd week of October 2017 and harvested in 3rd week of April 2018. Basal dose of mineral nitrogen (90 kg ha^{-1}) applied in three equal splits i.e. ⅓ each at first, third and fourth irrigation along with basal phosphorus (60 kg ha^{-1}) at the time of sowing was applied to all plots for maize cultivation. Field was irrigated six times during both 2017 and 2018 as flood irrigation at critical stages (after emergence, three leaves stages, knee height, tasseling/silking, grain development and grain filling). Weeds were controlled manually by hoeing after 2nd irrigation, and no herbicides were used. However, borers were controlled through Furadan (Carbofuran 3%) applied at the rate of 20 kg ha^{-1} after 2nd irrigation *i.e.* three leaves stage.

Observations and measurements

Composite soil samples were collected from experimental field from 20 cm depth before planting maize crop in 2017. However, three samples were collected from 20 cm depth in each plot after maize harvesting in 2017 and 2018 and combined to make a composite sample (from the same plots established in 2017 and 2018). Both before and after sowing, the composited samples were cleaned, grounded to 2 mm mesh size and stored for determination of soil total N or freshly process for soil mineral N as per the procedure given below. Samples were also collected from farmyard manure and humic acid, and analyzed for carbon, nitrogen, phosphorous and potash concentration as well as pH and electrical conductivity.

Plant growth parameters

Plants (m^{-2}), ear length, leaves plant^{-1}, leaf area plant^{-1}, leaf area index and plant height were worked out to know the growth response of maize in response to three types of treatments. The plants were counted across a single meter long row at three locations in each plot and converted to plants m^{-2}. Five ears were detached from plants in each plot and ears length was measured with common scale and averaged to find out the ear length. All leaves in five plants were counted at tasseling stage and were averaged to report leaves plant^{-1} data. Three leaves from top, middle and bottom, respectively were randomly detached from plants, and the width and length of all those leaves were measured using ordinary scale and averaged. The leaf area plant^{-1} was calculated as the product of leaf length, width, factor (0.69) and leaves plant^{-1}.

Soil analysis

Soil samples taken prior to experiment were used for determination of soil physical properties. Soil water suspension (1:5) was prepared by taking 10 g of dry soil and 50 ml of distilled water. The suspension was shaked for 1 hour on mechanical shaker, left for 30 minutes and then filtered. The filtrate was used for determination of soil pH using pH meter calibrated with 4 and 7 buffers. The soil EC was also determined using the same soil suspension with the help of soil EC meter following the procedure out lined by Rhoades (1996). The soil mineral nitrogen content was determined following the steam distillation procedure as reported by Keeney and Nelson (1982). The soil total nitrogen was determined as per the procedure of Bremner and Mulvaney (1982).

Statistical analysis

The data was analyzed as per the procedure of RCB design and means were compared using least significant differences (LSD) test at P ≤ 0.05 upon significant F-test (Jan *et al*., 2009). The correlation analyses were carried out to understand the positive and negative relationship of soil properties with maize growth parameters. The statistical analysis was carried out using statistical software Statistix ver. 8.1 (Analytical software, Florida) and graphs by Sigma plot ver. 14 (Systat. Software Inc., Chicago, IL).

Table 2: *Maize growth parameters in response to beneficial microbes (BM, L ha^{-1}), humic acid (HA, kg ha^{-1}) and farmyard manure (FYM, Mg ha^{-1}) during 2017 and 2018.*

Treatments	Leaves plant^{-1}	Leaf area (cm^{-2})	Leaf area index	Ear length (cm)	Plant height (cm)
	2017				
25-BM	12.6	3712 b	2.4 b	15.6 b	189 b
50- BM	12.6	3932 a	2.5 a	16.6 a	196 a
Significance	NS	**	*	**	**
3-HA	12.6	3658 c	2.3 b	16.1 ab	185 c
6-HA	12.6	3810 b	2.4 b	15.7 b	193b
9-HA	12.7	3998 a	2.5 a	16.6 a	199 a
$LSD_{0.05}$	NS	145	0.1	0.67	4.2
10-FYM	12.3 b	3542 c	2.2 c	15.5 b	186 b
15-FYM	12.6 ab	3858 b	2.5 b	16.1 ab	192 b
20-FYM	12.9 a	4067 a	2.6 a	16.7 a	199 a
$LSD_{0.05}$	0.4	145	0.1	0.7	4.2
Control	12.0 b	2251 b	1.4 b	12.9 b	160 b
Treated plots	12.6 a	3822 a	2.4 a	16.1 a	192 a
Significance	NS	**	**	**	**
	2018				
25-BM	12.7	3755 b	2.4 b	15.9 b	192 b
50- BM	13.0	4121 a	2.7 a	16.8 a	199 a
Significance	NS	**	**	**	**
3-HA	12.7	3745 b	2.4 b	15.9 b	187 c
6-HA	12.8	3969 a	2.5 b	16.5 a	194 b
9-HA	13.1	4100 a	2.7 a	16.6 a	204 a
$LSD_{0.05}$	NS	131	0.1	0.5	5.7
10-FYM	12.1 c	3648 b	2.3 b	15.5 c	186 b
15-FYM	13.0 b	4057 a	2.6 a	16.3 b	197 a
20-FYM	13.5 a	4109 a	2.7 a	17.3 a	202 a
$LSD_{0.05}$	0.4	131	0.1	0.5	5.7
Control	11.5 b	2136b	1.3 b	13.5 b	169 b
Treated plots	12.9 a	3938 a	2.5 a	16.3 a	195 a
Significance	**	**	**	**	**

**, **, NS mean significant at P ≤ 0.05, 0,01, and non-significant, respectively; Means of the same category followed by different letters are significantly different from each other at p ≤ 0.05 using LSD test.*

Results and Discussion

Maize growth response to BM, HA and FYM

The application of BM had no effects on leaves plant^{-1} but significantly increased the leaf area plant^{-1} (7.8%) and leaf area index from 2.4 to 2.6 based on two years data (Table 2). Similarly, the HA application had no significant effects on leaves plant^{-1} but had increased the leaf area (9.3%) and leaf area index both in 2017 and 2018 (Figure 2). The application of FYM at the rate of 15 Mg FYM ha^{-1} had more leaves plant^{-1} (13.2), but 20 Mg FYM ha^{-1} had maximum leaf area plant^{-1} (4088 cm^{-2}), and leaf area index (2.6) averaged over two-year data (Table 2). This indicates that doubling the amount of FYM from 10 to 20 Mg FYM ha^{-1} had increased leaves plant^{-1} by one leaf, leaf area plant^{-1} by 13.7% and leaf area index by 13% over two years data.

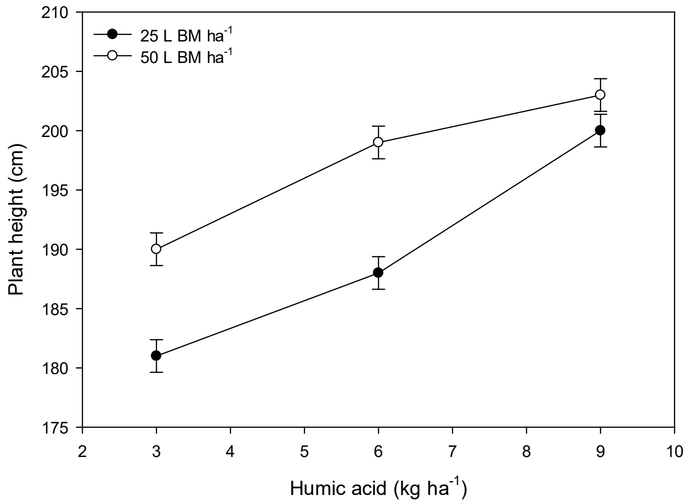

Figure 2: *The interactive response of farmyard manure (FYM) and humic acid (HA) for plant height of maize over two years. The vertical bars are standard error of means.*

Increasing the BM levels from 25 to 50 L ha^{-1} had significantly increased the ear length of maize by 6.4% in 2017 and 5.7% in 2018 and 6.4% when the data was analyzed combined over two years (Table 2). The application of 6 kg HA ha^{-1} had resulted in 15.7 cm ear length as compared to 16.6 cm ear length measured with 9 kg HA ha^{-1} in 2017. However, in 2018 increasing the HA from 3 to 9 kg ha^{-1} had increased the maize ear length from 15.9 to 16.6 cm, respectively. Increasing the HA levels by three times *i.e.* from 3 to 9 kg ha^{-1}, the ear length of maize over two years average data increased by 0.6 cm. The data indicates that increasing FYM from 10 to 20 Mg ha^{-1} had increased the ear length by 7.8% in 2017 as compared to 11.61% in 2018. The maize ears were lengthier for 20 Mg FYM ha^{-1} (17.0 cm) and shorter with 10 Mg FYM ha^{-1} (15.5 cm). Plant tallness increased by 7.3 cm (2018) with increasing BM from 25 to 50 L ha^{-1} (Table 2). Similarly, increasing the HA levels by three times *i.e.* from 3 to 9 kg ha^{-1}, the plant height of two years average data increased by 15.6 cm. The tallest plants (204.0 cm) were in 2018 when 20 Mg FYM ha^{-1} were incorporated in soil, as compared to dwarf plants been measured with 10 Mg FYM ha^{-1} (187.3 cm) in 2017. Similarly, increasing the FYM from 10 to 20 Mg ha^{-1} in 2018, the plant height of maize was increased by 16 cm. The average of two years data showed that doubling the levels of FYM *i.e.* up to 20 Mg FYM ha^{-1}, the plant height increased by 14.5 cm (Table 2). It was further noted that application of 20 Mg FYM ha^{-1} produced tallest plants (200.7 cm), followed by 15 Mg FYM ha^{-1} (194.2 cm) and shortest plant were measured with 10 Mg FYM ha^{-1} (186.2 cm).

The treated plots when compared to control had increased the number of leaves from 11.8 to 12.7, leaf area $plant^{-1}$ from 2194 to 3880 cm^{-2} and leaf area index from 1.4 to 2.5, plant tallness by 29.3 cm, and ear length by 2.9 cm. (Table 2). The interaction between HA×FYM (Figure 2) indicated that increasing the levels of FYM had increased the ear length both in 2017 and 2018 when 3 kg HA ha^{-1} was applied. However, with application of HA greater than 3 kg ha^{-1} the increased FYM had no significant differences for ear length in 2017 and 2018. The interactive response of BM×HA showed that plant tallness increased with increasing level of HA both in 2017 and 2018 across both levels of BM (Figure 3). However, the increases in plant tallness were prominent with 50 L ha^{-1} over 25 L ha^{-1} over both year data average.

Maize growth contributing parameters like plant height, leaves $plant^{-1}$, ear length, leaf area and leaf area index was greater with 50 L BM ha^{-1} compared to 25 L BM ha^{-1}. The increased growth contributing parameters might be related to the improved individual plant performance (Khan *et al*., 2014) as a result of greater mineral N availability due to higher decomposition of manure in the presence of microbes (Khan *et al*., 2019). The increased mineral N is directly related to the increased growth contributing parameters of maize (Khan *et al*., 2014), and hence the crop growth increased. Other possible mechanisms could be the improved moisture availability (Jia *et al*., 2013), soil condition (Singh *et al*., 2015), crop stand (Ibrahim and Khan, 2017). These findings are in agreement with earlier researcher who obtained improved growth parameters of maize due to microbes' addition (Haji *et al*., 2014). Increasing HA application three times from 3 to 9 kg ha^{-1} had increased the maize leaves $plant^{-1}$, ear length, leaf area and leaf area index both in 2017 and 2018. The increased growth parameters could be related to the improved soil properties as a result of chelating properties of HA (Mackowiak *et al*., 2001). The chelating properties of HA had enhanced the nutrients availability (Mackowiak *et al*., 2001) which might have been increased the plant photosynthesis capability and hence the growth of maize crop.

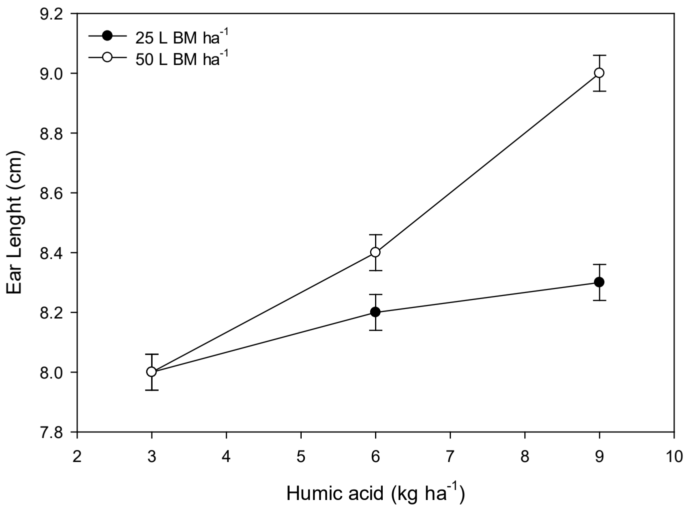

Figure 3: *The interactive response of beneficial microbes (BM) and humic acid (HA) for ear length of maize over two years. The vertical bars are standard error of means.*

The application of 20 Mg FYM ha^{-1} had increased leaves $plant^{-1}$, leaf area, leaf area index, plant height, and ear length of maize. The increased leaves plant and associated leaf area as well as plant height might be related to the improved permeability of soil (Jat *et al*., 2019), water storage capacity of soil and optimized soil temperature (Jia *et al*., 2013). These results are in line with the finding of Khan *et al*. (2009), who reported increased growth and biomass of maize due to the application of FYM when compared to control plots. Similarly, when the higher amount of FYM was added mineral nitrogen availability increased (Khan *et al*., 2019) as a result of increased decomposition of FYM (Bowles *et al*., 2014). The direct addition of FYM is considered as addition of nutrients which prolong the vegetative period of maize (Khan *et al*., 2014) and thus might have improved the increased maize growth. These results agree with the findings of earlier researchers like Khan *et al*. (2009), who documented increases in growth in response to higher usage of FYM *i.e.* 20 Mg FYM ha^{-1} to either lower levels or control plot.

Maize growth in response to soil properties

The correlation analysis of soil total as well as mineral nitrogen contents with maize growth parameters like plant m^{-2}, leaves $plant^{-1}$, leaf area, LAI, grain yield and grain N contents is provided in Figure 4. It was observed from the correlation analysis that grain yield positively correlated with soil mineral N, plant height, ear length, leaves $plant^{-1}$, leaf area and leaf area index. However, the relationship of grain yield with soil total N and plants m^{-2} was found non-significant. Similarly, most of maize growth parameter were positively correlated with each other, except plants m^{-2}. Among these relationships, the relationship among the growth parameters of maize *i.e.* leaf area and leaf index with grain yield was stronger than the relationship of grain yield with ear length, and leaves $plant^{-1}$. It was further observed that mineral N had strong effects on growth of maize whereas total N had no effects on maize growth parameters.

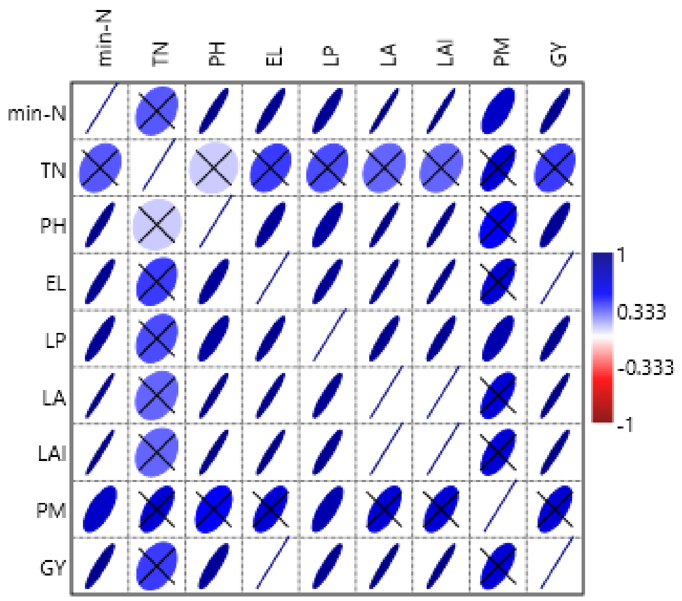

Figure 4: *Correlation matrix of soil nitrogen status i.e. min-N (mineral nitrogen) and TN (total nitrogen) with maize growth parameters i.e. GY (grain yield), PM (plants m^{-2}), LAI (Leaf are index), LA (Leaf area), LP (leaves $plant^{-1}$), EL (ear length), and PH (Plant height) averaged over two years data of all treatments. The crossed ellipse represents non-significant (P ≤0.0) correlations, and thinner size ellipses have strong correlations.*

The low soil organic matter (Khan *et al.*, 2019) of the experimental site is the main obstacle for lower growth of maize and associated soil fertility indices. Therefore, the direct addition of FYM from external source may provide nutrients (Khan *et al.*, 2015) to the soil, which could be made available due to the improved microbiological properties (Odlare *et al.*, 2008) of soil in the presence of BM and HA, and thus might have improved the maize growth as documented by positive and significant relationship in the current studies. The increased BM can improve the decomposition (Ma *et al.*, 2020) of added FYM, which was further facilitated as a result of soil chelating properties (Mackowiak *et al.*, 2001) by HA addition and the energy provision by FYM for microbes (Zhou *et al.*, 2019), and thus had a positive impact on maize growth.

Conclusions and Recommendations

Doubling the beneficial microbial solution increased maize growth. The addition of humic acid has positive effects on maize growth in term of plant height, leaves $plant^{-1}$, leaf area and leaf area index. Grain yield was positively correlated with soil mineral N, leaves $plant^{-1}$, leaf area, leaf area index, plant height and ear length. Based on the conclusion and results of the studies, it is recommended, that application of 50 L ha^{-1} beneficial microbes should be applied with 6-9 kg HA ha^{-1} and 20 Mg FYM ha^{-1} for improving the mineral N availability and hence the maize growth in the studied area.

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Novelty Statement

Increasing beneficial microbes, humic acid and farmyard manure levels had increased the maize growth in term of plant height, leaf area and leave plant. The grain yield was positively correlated with soil mineral N, leaves plant-1, leaf area/index, plant height an dear length.

Author's Contribution

Izaz Hussain: Carried out research & drafted the manuscript.

Ahmad Khan: Analyzed the data, carried out tab-

ulations/figures of data, and did overall supervision during research.
Habib Akbar: Conceived the idea and helping in designing of experiment

Conflict of interest
The authors declared no conflict of interest.

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