CO-APPLICATION OF EFFECTIVE MICROBES WITH BIOCHAR AND FARMYARD MANURE ENHANCES MAIZE GROWTH AND YIELD

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Abstract

Soil fertility has consistently declined in the wake of injudicious use of synthetic fertilizers in exhaustive crops. It is the need of time to develop sustainable approaches that may maximize crop yield without deteriorating soil fertility. An experimental trial was conducted at Agronomy Research Farm, The University of Agriculture, Peshawar, to find out whether exogenously applied soil microbes may enhance maize (Zea mays L.) growth and production when applied in the presence of biochar and farmyard manure (FYM). We applied two levels of effective microbes (EM; with and without EM) along with three application rates of biochar (0, 7.5 and 15 t ha^{-1}) and three levels of FYM (no FYM, fresh FYM and composted FYM). A randomized complete block design was used with each treatment replicated thrice. Effective microbes non-significantly delayed tasseling, silking and physiological maturity. Maize phenology delayed with a higher biochar application rate in the presence of composted FYM. A higher biochar rate (15 t ha^{-1}) along with fresh FYM produced taller plants and heavier grains while a moderate biochar rate (7.5 t ha^{-1}) in the presence of composted FYM produced wider leaves and numerous grains ear^{-1}. A moderate biochar rate and composted FYM recorded higher stover, grain and biological yield in the presence of effective microbes. This may imply that effective microbes may efficiently benefit from the presence of biochar and manures and enhance maize production significantly. However, care should be taken in choosing biochar application rate and manures should be properly decomposed prior to field application in short duration crops such as Maize.

Key words

Biochar
Effective microbes
Integrated nutrient management
Maize

1. Introduction

In the last fifty years, intensive use of inorganic fertilizers has globally enhanced crop productivity manifold in the face of growing global population and shrinking per capita land, however, it has also led to an extensive decline in soil fertility. A sustainable approach towards meeting plants' nutritional requirements relies on an integrated use of organic and inorganic soil amendments. This approach is aimed at sustainably enhancing crop production while minimizing the negative impacts. Organic soil amendments include manures, residues and other farm wastes. Biochar is one such organic soil amendment which can be prepared from such organic biomasses. It has recently gathered attention for its soil quality enhancing properties. It is a pyrolyzed product of organic biomass, i.e., a product of anaerobic combustion of organic material such as wood, plant residues, and animal excreta at high temperatures. It has been termed as a perfect soil conditioner due to its positive impact on a wide range of soil physical properties. It has been reported to improve soil structure, increase nutrient retention in soil and decrease nutrient leaching, improve soil-plant-water relations, and expand soil biodiversity by increasing microbial biomass and boosting its activity (Lehmann *et al*., 2006; Steiner *et al*., 2007; Atkinson *et al*., 2010; Kasozi *et al*., 2010; Lal, 2011; Lehmann *et al*., 2011; Thies and Rillig, 2012). Soil biota enhancement is perhaps the most important function of biochar from an agroecological perspective. Microbial communities in soil are endangered by the lack of food in soil and the presence of soil microarthropods. Several researchers have reported the positive impact of biochar on living soil communities. Biochar improves the status of soil biota by protecting them against predatory microbes and by acting as medium from which these microbes harness water and nutrients (Liang *et al*., 2010). Both of these functions of biochar stem from its complex structure which is composed of micro, meso, and macro-pores (McCormack *et al*., 2013); (Warnock *et al*., 2007).

Soil microbes that are beneficial for plants occur naturally in soil. Soil amendments change their dynamics in the soil either positively or negatively. These microbes can also be multiplied in controlled conditions and can be applied to the soil afterwards. Effective Microorganisms (EM) is one such technology which involves multiplication and exogenous application of beneficial microorganisms (Higa, 2001, 1991). In this technology, dormant species of microbes such as Fermenting fungi, Photosynthetic bacteria, Lactic acid bacteria, Yeasts and Actinomyces are multiplied in favorable conditions and applied to the soil afterwards. These microbes then perform functions in the soil that are beneficial for plants. These microbes work synergistically with other microbes and convert a degraded microbial ecosystem to one that is productive.

Research on biochar has been previously focused on the acidic soils of tropical and temperate regions. The improvements brought about by biochar in these soils have been obvious because of its alkaline nature and excellent buffering capacity (Major *et al*., 2010). Very little research has been done on the alkaline soils of subtropical and semi-arid regions of the world such as Pakistan. Maize, being the third most important crop of Pakistan in terms of production and people needs, is an exhaustive crop both in terms of water and nutrients use. Farmers in pakistan use enormous amounts of synthetic fertilizers to boost its production. This has led to severe degradation of soils that are currently under maize cultivations. These factors make biochar an ideal candidate for the reclamation of such degraded soils and for the improvement of important soil biological communities.

2. Materials and methods

2.1. Experimental site

The experimental trial was carried out at Agronomy Research Farm of the University of Agriculture Peshawar during Kharif season 2018. The climate of the trial site is semi-arid subtropical, having warm summers and hot winters. Soil is well drained, silty clay loam in texture and slightly alkaline in nature. Soil is deficient in organic matter and other macro-nutrients, while potassium is sufficient.

2.2. Biochar, FYM and effective microbes

A stainless-steel pyrolysis unit was used for the preparation of biochar from acacia wood cuttings. The kiln had a temperature range of 1000 °C. The process was initiated with a 20-minute ignition period followed by the maximum temperature of 670 °C and an average temperature of 450 °C for the next three hours.

Fresh farmyard manure (FYM) was collected from the cattle farm of the University and applied to the respective plots a day before sowing. Composted FYM was once fresh FYM that was allowed to decompose on its own in closed pits for two months.

Effective microbes (EM) are available as dormant microbes in a commercially available product called Bioaab. The product contains five strains of microorganisms i.e., photosynthetic bacteria, lactic acid bacteria, actinomycetes, yeasts, and fermenting fungi. The dormant microbes (5%) are activated by mixing it with molasses (5%) and water (90%) and hence making a 100% v/v solution. The activation process takes approximately 10 days until the pH of the solution drops to 4 which shows that the microbes have been awakened. The solution is then applied to the soil before sowing at an application rate of 1000 liters ha^{-1}.

2.3. Experimental design and treatments application

The experiment was laid out in RCB design with three replications. The treatments composed of three biochar rates (0, 7.5 and 15 t ha^{-1}), three FYM levels (no FYM, fresh FYM and composted FYM) and two EM application levels (without and with EM). Maize hybrid variety (CS-200) was sown on 1st July 2018 and harvested on 10th October 2018. All agronomic practices including synthetic fertilizer application, irrigation, and pesticide application were kept the same for all plots.

2.4. Agronomic measurements and crop harvest

Days to tasseling and silking were counted from the day of sowing until the emergence of tassels and silks in 80% plants of each plot while days to maturity were determined by the formation of black spot on the grain's base. Plant height was measured using meter rod from plants base to the tassel's tip. Leaf area was found by multiplying the length and width of the leaf with a correction factor (0.71). Three central rows of maize crop were harvested on 10th October, cobs were removed and threshed, and data were taken on thousand grains weight, ears plant^{-1}, grains ear^{-1}, grain and stover yield.

2.5. Statistical analysis

Data were analyzed using analysis of variance (ANOVA) test with normal distribution and log-transformed when required. Three-way ANOVA was applied to test the effect of biochar, FYM and EM on crop variables. Data in the tables are presented as means followed by standard error values. SPSS v. 21 software was used for further analysis.

3. Results

3.1. Days to tasselling, silking and physiological maturity

Days to silking and physiological maturity were highly significantly affected by FYM and biochar while days to tasseling were significantly affected by FYM only (Table 1). The Effect of EM was non-significant for all phenological parameters. Tasseling, silking and physiological maturity delayed in plots receiving composted FYM with increasing biochar rate generally in the presence of effective microbes.

3.2. Leaf area, Leaf area index and plant height

Leaf area was significantly affected by FYM and biochar while its index was significantly affected by effective microbes (Table 2). A higher value of leaf area index was shown in plots amended with effective microbes. EM had minimal effect on maize plant height. A moderate biochar rate (7.5 t ha^{-1}) produced wider leaves compared to a higher biochar rate (15 t ha^{-1}) or no biochar. In the presence of EM, composted FYM showed higher leaf area. A higher biochar rate performed better compared to a moderate level in terms of plant height, while fresh FYM produced taller plots compared to composted or no FYM at all.

3.3. Grains ear^{-1} and thousand grains weight

Grains ear^{-1} and thousand grains weight were found higher in plots with effective microbes amendment (Table 3). Although the effect of biochar and FYM was found non-significant for both parameters, generally higher grains ear^{-1} were found with a moderate biochar rate (7.5 t ha^{-1}) while heavier grains were recorded with a higher biochar application rate (15 t ha^{-1}). Composted FYM showed higher values of both parameters compared to fresh FYM.

3.4. Stover and grain yield

Stover and grain yield were significantly affected by effective microbes, biochar and FYM (Table 4). In the presence of effective microbes, a moderate biochar application rate (7.5 t ha^{-1}) and composted FYM produced higher grain and stover yield followed by a higher biochar rate and fresh FYM. Least values of these parameters were recorded in the absence of microbes, biochar and FYM.

3.5. Biological yield and harvest index

Effective microbes, biochar, and FYM highly significantly affected the biological yield of maize while the effect of all three treatments was non-significant for harvest index (Table 5). Similar to that of stover and grain yield of maize, higher biological yield was recorded with the application of effective microbes, a moderate biochar application rate (7.5 t ha^{-1}) and composted FYM.

Table 1: Days to tasseling, silking and physiological maturity of maize as affected by FYM, EM and biochar rates

Rate of biochar (t ha^{-1})	**Days to tasseling**					
	-EM			+EM		
	F-FYM	C-FYM	No FYM	F-FYM	C-FYM	No FYM
15	56.7 (0. 29)	57.0 (0.19)	54.3 (0. 29)	55.0 (0.38)	56.3 (0. 22)	54.3 (0. 29)
7.5	55.3 (0. 29)	55.7 (0.40)	54.0 (0.38)	55.3 (0.59)	56.7 (0. 22)	53.7 (0. 29)
0	54.7 (0.40)	54.7 (0.29)	53.7 (0.22)	54.7 (0.11)	56.3 (0. 22)	53.3 (0. 29)
ANOVA	FYM***, B^{ns}, EM^{ns}, $B\times EM^{ns}$, $FYM\times EM^{ns}$, $B\times FYM^{ns}$, $B\times FYM\times EM^{ns}$					
	Days to silking					
15	61.0 (0.00)	63.0 (0.19)	60.7 (0.40)	61.3 (0.33)	63.0 (0.29)	60.3 (0.29)
7.5	60.7 (0.48)	60.7 (0.48)	59.0 (0.67)	60.0 (0.29)	61.7 (0.33)	59.0 (0.33)
0	59.3 (0.29)	60.3 (0.44)	58.3 (0.11)	60.0 (0.22)	62.3 (0.22)	59.3 (0.29)
ANOVA	FYM**, B*, EM^{ns}, $B\times EM^{ns}$, $FYM\times EM^{ns}$, $B\times FYM^{ns}$, $B\times FYM\times EM^{ns}$					
	Days to physiological maturity					
15	92.7 (0.29)	93.0 (0.19)	90.7 (0.22)	92.3 (0.29)	94.0 (0.19)	90.0 (0.19)
7.5	91.3 (0.56)	91.3 (0. 11)	87.0 (0.00)	90.3 (0.59)	93.0 (0.19)	87.7 (0.22)
0	87.7 (0.29)	88.3 (0. 11)	86.3 (0.11)	87.3 (0. 11)	90.3 (0. 11)	87.0 (0.19)
ANOVA	FYM***, B***, EM^{ns}, $B\times EM^{ns}$, $FYM\times EM^{ns}$, $B\times FYM^{ns}$, $B\times FYM\times EM^{ns}$					

Values are three replicates means with standard errors in brackets (n=3). ***P*<0.01, **P*<0.05, ****P*<0.001, ns=non-significant. FYM=Farmyard manure, EM=Effective microbes, B=Biochar rate, F-FYM=Fresh FYM, C-FYM=Composted FYM

Table 2: Leaf area (cm^2), Leaf area index and plant height (cm) of maize as affected by FYM, EM and biochar rates

Rate of biochar (t ha^{-1})	**Leaf area (cm^2)**					
	-EM			+EM		
	F-FYM	C-FYM	No FYM	F-FYM	C-FYM	No FYM
15	467 (3)	464 (2)	465 (5)	513 (14)	462 (5)	473 (2)
7.5	483 (8)	489 (3)	465 (7)	490 (8)	523 (13)	467 (9)
0	473 (10)	446 (15)	409 (4)	432 (10)	505 (9)	387 (9)
ANOVA	FYM*, EM^{ns}, B*, $B\times EM^{ns}$, $FYM\times EM^{ns}$, $B\times FYM^{ns}$, $B\times FYM\times EM^{ns}$					

	Leaf area index					
15	3.9 (0.07)	3.5 (0.07)	3.8 (0.05)	4.2 (0.21)	3.9 (0.03)	3.8 (0.09)
7.5	4.1 (0.07)	4.2 (0.03)	3.3 (0.06)	3.9 (0.08)	4.7 (0.13)	3.8 (0.02)
0	3.7 (0.07)	3.6 (0.08)	3.6 (0.08)	3.2 (0.09)	4.1 (0.13)	3.1 (0.06)
ANOVA	FYM^{ns}, EM*, B^{ns}, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM^{ns}					
	Plant height (cm)					
15	271 (0.8)	257 (1.2)	263 (1.0)	270 (0.1)	270 (0.5)	260 (2.4)
7.5	272 (2.3)	264 (1.1)	258 (2.1)	268 (1.0)	264 (1.8)	257 (1.6)
0	254 (0.4)	255 (2.1)	255 (0.9)	264 (2.5)	267 (1.2)	257 (0.6)
ANOVA	FYM*, EM^{ns}, B*, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM^{ns}					

Values are three replicates means with standard errors in brackets (n=3). ***P*<0.01, **P*<0.05, ****P*<0.001, ns=non-significant. FYM=Farmyard manure, EM=Effective microbes, B=Biochar rate, F-FYM=Fresh FYM, C-FYM=Composted FYM

Table 3: Grains ear^{-1} and thousand grains weight (g) of maize as affected by FYM, EM and biochar rates

Rate of biochar (t ha^{-1})	**Grains ear^{-1}**					
	-EM			+EM		
	F-FYM	C-FYM	No FYM	F-FYM	C-FYM	No FYM
15	462 (36)	461 (12)	425 (19.7)	466 (30.2)	484 (41.8)	466 (35.3)
7.5	493 (26.2)	504 (11.7)	425 (19.7)	486 (24.5)	501 (9.9)	466 (35.3)
0	420 (12.3)	437 (28.6)	415 (10.5)	451 (16.1)	461 (11.9)	507 (17.6)
ANOVA	FYM^{ns}, B^{ns}, EM*, B×FYM^{ns}, FYM×EM^{ns}, B×EM^{ns}, B×FYM×EM^{ns}					
	Thousand grains weight (g)					
15	299 (20.3)	310 (11.7)	304 (14.9)	319 (6.6)	313 (11.6)	307 (12)
7.5	298 (15.5)	306 (12.6)	306 (13)	315 (8.1)	311 (9.5)	311 (13.1)
0	270 (12.1)	291 (5.3)	281 (4.6)	295 (17.9)	315 (7.1)	307 (11)
ANOVA	FYM^{ns}, B^{ns}, EM*, B×FYM^{ns}, FYM×EM^{ns}, B×EM^{ns}, B×FYM×EM^{ns}					

Values are three replicates means with standard errors in brackets (n=3). ***P*<0.01, **P*<0.05, ****P*<0.001, ns=non-significant. FYM=Farmyard manure, EM=Effective microbes, B=Biochar rate, F-FYM=Fresh FYM, C-FYM=Composted FYM

Table 4: Stover and grain yield (kg ha^{-1}) of maize as affected by FYM, EM and biochar rates

Rate of biochar (t ha^{-1})	**Stover yield (kg ha^{-1})**					
	-EM			+EM		
	F-FYM	C-FYM	No FYM	F-FYM	C-FYM	No FYM
15	12963 (267)	13519 (211)	13333 (64)	14259 (216)	13667 (360)	11815 (65)
7.5	13111 (98)	13741 (271)	13074 (208)	13407 (69)	14296 (246)	13815 (49)
0	12222 (43)	13111 (259)	10704 (199)	12741 (25)	13778 (21)	13370 (123)
ANOVA	FYM*, B*, EM*, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM^{ns}					
	Grain yield (kg ha^{-1})					
15	7000 (288)	7593 (33)	8000 (86)	8074 (187)	8889 (113)	7185 (33)
7.5	8519 (69)	8148 (89)	7889 (140)	8222 (128)	8704 (62)	8704 (179)
0	6926 (137)	7741 (158)	7111 (21)	7037 (86)	8259 (118)	8370 (89)
ANOVA	FYM*, B**, EM**, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM*					

Values are three replicates means with standard errors in brackets (n=3). ***P*<0.01, **P*<0.05, ****P*<0.001, ns=non-significant. FYM=Farmyard manure, EM=Effective microbes, B=Biochar rate, F-FYM=Fresh FYM, C-FYM=Composted FYM

Table 5: Biological yield (kg ha^{-1}) and harvest index of maize as affected by FYM, EM and biochar rates

Rate of biochar (t ha^{-1})	**Biological yield (kg ha^{-1})**					
	-EM			+EM		
	F-FYM	C-FYM	No FYM	F-FYM	C-FYM	No FYM
15	19963 (445)	21111 (241)	21333 (150)	22333 (74)	22556 (316)	19000 (57)
7.5	21630 (162)	21889 (278)	20963 (343)	21630 (155)	23000 (252)	22519 (158)
0	19148 (150)	20852 (415)	17815 (194)	19778 (107)	22037 (136)	21741 (211)
ANOVA	FYM**, B***, EM**, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM**					
	Harvest index					
15	34.9 (0.87)	36.0 (0.27)	37.5 (0.14)	36.2 (0.87)	39.6 (0.81)	37.8 (0.21)
7.5	39.4 (0.09)	37.3 (0.53)	37.6 (0.14)	38.0 (0.37)	37.9 (0.45)	38.6 (0.53)
0	36.1 (0.46)	37.1 (0.09)	40.0 (0.48)	35.6 (0.25)	37.4 (0.31)	38.5 (0.07)
ANOVA	FYM^{ns}, B^{ns}, EM^{ns}, B×EM^{ns}, FYM×EM^{ns}, B×FYM^{ns}, B×FYM×EM^{ns}					

Values are three replicates means with standard errors in brackets (n=3). **P<0.01, *P<0.05, ***P<0.001, ns=non-significant. FYM=Farmyard manure, EM=Effective microbes, B=Biochar rate, F-FYM=Fresh FYM, C-FYM=Composted FYM

4. Discussion

Biochar significantly influenced growth and production of maize crop. It elongated the vegetative growth of maize, which was depicted in the form of delayed tasseling, silking, and physiological maturity. A long vegetative stage resulted in enhanced plant development and was shown as enhanced plant height, increased leaf area, numerous and heavier grains, and higher grain and stover yield. The positive effects of biochar are generally less attributed to its nutrient content and more to its role as a soil conditioner. In fact, according to metadata research by (Zhu *et al*., 2015), 65–80% of biochar's positive role is due to its indirect effect on soil fertility while the remaining 20–35% of the effect can be attributed to its nutrient content. Indirect effects on soil fertility include a buffering effect on soil pH, increased water holding capacity, improved bulk density, and enhanced cation exchange capacity (Glaser *et al*., 2002). Biochar has sufficient P and it also has enough K in its ash content, however, it has an antagonistic effect on soil N and tends to decrease it in the applied soil. It is infact due to the high C:N ratio of the biochar amended soil which results in a slow decomposition rate of any organic matter which in our case were fresh and decomposed FYM.

Several researchers have reported no significance improvement in crop growth and production with biochar addition (Free *et al*., 2010; Tammeorg *et al*., 2014). (Lyu *et al*., 2016) even observed negative impact and recorded a decline in crop yield with biochar application.

However, a systemic analysis of the biochar experiments reveals that possible benefits from biochar application are strictly dependent on environment and soil of the trial sites. Highly weathered and stressed soils are more responsive to biochar application. This makes biochar an ideal solution for the reclamation of problem soils. Studies have also shown that benefits of biochar are dependent on its application rate with the observation that higher rates cause a decline in crop yield. In this trial, a yield decline was observed with a higher biochar rate (15 t ha^{-1}) and maximum yield was obtained with a moderate application rate (7.5 t ha^{-1}). These kinds of declines usually occur in alkaline and high pH soils (Rajkovich *et al*., 2012). The negative impacts usually fade with time and areas receiving higher biochar rates show improved performance later. Besides this, biochar has been reported to contain certain harmful compounds which suppress soil microbes and thus hinder plant growth. These compounds include carboxylic acids, ketones, phenols, benzene, furans, methoxyphenols, and polycyclic aromatic hydrocarbons (PAHs). Mostly, these compounds are created at pyrolysis temperatures lower than 400 ^{o}C (Lyu *et al*., 2016). Persistent free radicals (PFRs) are also formed during pyrolysis; however, they are soon stabilized (Truong *et al*., 2020). The harmful effects of most of these compounds vanish with time and hence biochar application proves promising in the long run.

Organic sources (i.e., farmyard manure) notedly improved maize growth and yield in our trial. It delayed phenological traits, improved plant physiological traits such as plant height and leaf area, and increased yield. (Kareem *et al*., 2017) with poultry manure and (Amanullah, 2015) with cattle manure along with PSB (phosphate solubilizing bacteria) reported delayed tasseling, silking and physiological maturity. A prolonged vegetative stage can be attributed to the enhanced availability of nitrogen to the plants. Farmyard manures have sufficient nitrogen and if made available to plants by the action of microbes, it can delay the onset of reproductive stage (Dauda *et al*., 2008); (Akongwubel *et al*., 2012). FYM application increased plant height in our trial. Our findings are supported by (Mitchell and Tu, 2005), who recorded increased plant height with poultry manure. (Verma *et al*., 2018) with vermicompost and (Ravi *et al*., 2012) with FYM application found similar resuls. This can also be attributed to increased nutrient supply with FYM application which could enhance the growth of plants apical meristims (Farhad *et al*., 2009). Our findings about increase in leaf area and its index are supported by (Nehra *et al*., 2001) and (Sanwal *et al*., 2007) who recorded higher leaf area with vermicompost application. Manures can supply sufficient plant nutrients which could then intensify plant assimilation, increase leaf cell division and hence result in leaves enlargement (Kareem *et al*., 2017). A wider leaf has an expanded photosynthetic apparatus and hence it can result in enhanced light interception. This means improved photosynthetic activity, assimilates production and translocation, and hence increased growth and production. This was depicted by increased yield and yield attributes in this trial. Our results about improved yield and yield components with FYM application are supported by a variety of researchers. (AM and Morsy, 2017) with sheep manure and compost, (Yigermal *et al*., 2019) with combined application of FYM and NPK and (Farhad *et al*., 2009) with poultry manure application recorded similar results.

Effective microbes improved maize growth and production. Our findings are supported by a plethora of researchers testing it on various crops such as maize (Rasool *et al*., 2008), rice (Javaid, 2010), wheat (Hati *et al*., 2006), cotton (Blaise *et al*., 2021), soybean and Mung bean (Javaid and Bajwa, 2011). (Hu and Qi, 2013) recorded improved wheat performance with EM application. They reported improved plant height and increased biomass and hence greater grain and biological yield with EM aplication. (Sabeti *et al*., 2017) also reported taller plants with EM application. Reseachers attributed this positive impact to the increased organic matter decomposition in EM amended plots which resulted in enhanced nutrient release and better root absorption.

The improvements in maize growth and yield with EM application may be due to two reasons (Yamada and Xu, 2001). Firstly, increased microbial activity increases organic matter decomposition which results in greater nutrient release and increased subsequent absorption by plant roots. Secondly, the increased decomposition rates in the presence of effective microbes results in the release of phytoharmones which hasten the mineralization process and hence cause a further exponential increase in the decomposition process and hence enhanced nutrient release (Daly and Arnst, 2005). The process intensifies even more when EM is co-applied with organic matter which in our trial were fresh and decomposed FYM. (Khaliq *et al*., 2006) obtained comparitively higher yield when EM was applied in combination with organic manures compared to its sole application or its combination with inorganic fertilizers. (Yamada and Xu, 2001) reported enhanced initial growth when EM was co-applied with NPK, however, in other treatments where EM was applied with organic manure, plants maintained vigorous growth throughout plants lifecycle.

Several researchers have shown no improvements or even negative outcomes with EM application. However, most of the trials reporting such outcomes are generlly short duration trials. These findings have been nullified by many researchers who performed long term and periodic trials on EM application. (Gami *et al*., 2001) in a twenty year experiment, (Hu and Qi, 2013) in an

eleven year trial, and (Singh *et al*., 2007) in an eight year research found significantly positive influences not only on the experiemntal crops, but also on overall soil fertility. (Olle and Williams, 2013) in a metadata analysis recorded that 84% of the trails on EM report positive results, 7 % reports a decline in soil quality or plant produce, while 9% observe no significance difference. This proves the higher ratio of EM efficacy.

5. Conclusions and Recommendations

Maize crop was responsive to addition of effective microbes and its co-application with biochar and farmyard manure. All of the treatments enhanced maize vegetative growth and the effect was obvious as enhanced plant growth in the form of taller plants and wider leaves. The effect of effective microbes was not pronounced in the early plant stages, however, its impact was obvious in the later stages. Delayed onset of reproductive stage gave enough time to assimilates in the treated plots to pronounce their effect in the form of increased yield and enhanced yield components. A moderate biochar rate (7.5 t ha^{-1}) and composted FYM performed better in this regard in comapsrison to higher biochar rate (15 t ha^{-1}) and fresh FYM. Hence, it was concluded that effective microbes enhance maize growth and yield in the presence of biochar and farmyard manure.

It is recommended that nothing goes to waste on farm and any kind of organic biomass may be pyrolized in a proper way to get biochar. This trial tested biochar rates for maize growth and yield enhancement, however, several other physical properties of biochar such as production temperature, particle size and biochar activation may be tested for efficiency in combination with effective microbes application. Effective microbes can be multiplied on farm with the help of animal waste. Same microbes can also be used to decompose farmyard manure and applied to short duration crops for faster nutrient release.

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