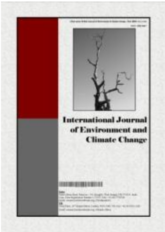

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Synergism of Organic Manure and Mycorrhizae Along with Inorganic Fertilizers on Crop Growth and Yield of Maize

Rajat Singh [a], Robin Kumar [a*], Neeraj Kumar [a*], Digvijay Singh [b] and Pravendra Kumar Pathak [a]

[a] Department of Soil Science and Agricultural Chemistry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya- 224229 (U.P.), India.
[b] Department of Agronomy, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya- 224229 (U.P.), India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted during Rabi 2021-22 to evaluate the synergistic effect of organic manure and mycorrhizae on soil health and crop performance in winter maize (*Zea mays* L.) at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya- 224229. The experiment was laid out in randomized block design and replicated thrice. The experiment consists of 8 treatments i.e. T_1 (Control),T_2 (100% RDF), T_3 (80% RDF + 20% VC+ Mycorrhizae), T_4 (80% RDF + 20% PM+ Mycorrhizae), T_5 (60% RDF + 40% VC+ Mycorrhizae), T_6 (60% RDF+ 40% PM+ Mycorrhizae), T_7 (60% RDF+ 20% PM + 20 % VC+ Mycorrhizae), T_8 (50% VC+ 50% PM+ Mycorrhizae). Results showed that growth and yields were substantially improved under Treatment T_6 (60% RDF+ 40% N- PM+ Mycorrhizae) viz. plant height (cm), leaf area index (LAI), dry matter accumulation (kg ha^{-1}), cob length (cm), number of grain rows cob $^{-1}$, number of grains cob^{-1}, test weight (g), weight of cob (g), grain yield (q ha^{-1}), stover yield (q ha^{-1}) and biological yield (q ha^{-1}). Conclusively, synergistic incorporation of inorganic fertilizers with organic manure and mycorrhizae can be used with optimum rates to improve crop growth and productivity on sustainable basis.

**Corresponding author: E-mail: khatiyanr@gmail.com;*

Keywords: Organic manure; vermicompost; synergistic; maize; mycorrhizae.

ABBREVIATIONS

SOM : Soil organic matter;
CF : Inorganic Fertilizers;
CEC : Cation exchange capacity;
N : Nitrogen;
P : Phosphorus;
K : Potassium;
Ca : Calcium;
Mg : Magnesium;
VC : Vermicompost;
PM : Poultry manure.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most flexible crops among all cereals that are produced globally under various agro-climatic conditions. Because it has a significantly larger production potential than all cereal crops, as a result, it is known as the "queen of cereals". 61 per cent of maize produced worldwide is utilised as animal feed, 17 per cent as food, and 22 per cent as industrial feed, but in India, 52 per cent is used for animal feed, 23 per cent for human food and the rest is used by industries. Despite the fact that 80 percent of maize is grown as a rainfed crop, the maize crop provides around 9% to overall food production.

It is grown on around 160 million hectares (ha) of land in 166 nations with a vast range of soil, temperature, biodiversity, and management approaches. Maize is the most important food cereal crop, accounting for 40% of world food output (> 800 Mt.) per year. The United States is the world's top maize producer, accounting for over 35% of total maize output, followed by China, which accounts for more than 20% of global maize production on the same land as the United States. Maize is the most productive crop in the United States (> 10 t ha^{-1}) and is twice as productive as the global average (5.3 t ha^{-1}). India's production is just half that of the rest of the world [1].

After rice and wheat, maize is India's third most significant crop. India is now ranked 4^{th} in terms of area and 8^{th} in terms of maize output in the globe. Maize was cultivated on 8.80 million hectares in India in 2019, with a production of 22.56 million tonnes and a productivity of 2563 kg ha^{-1}, with Karnataka, Maharashtra, Madhya Pradesh, and Tamil Nadu contributing the most [2]. Madhya Pradesh and Karnataka have the most maize-growing land (15 percent), followed by Maharashtra (10 percent), Rajasthan (9.18 percent), and Uttar Pradesh (8 percent). Maize was grown on 0.87 million hectares (9.18 percent of all land in India) and produced 1.64 million tonnes (5.71 percent of all land in India) with a productivity of 1884 kg ha^{-1} in Rajasthan [3].

Use of organic manures alongside inorganic fertilizers often lead to increased soil organic matter (SOM), soil structure, water holding capacity and improved nutrient cycling and helps to maintain soil nutrient status, cation exchange capacity (CEC) and soil's biological activity [4]. The use of organic manure to meet the nutrient requirement of crop would be an inevitable practice since organic manures generally improve the soil physical, chemical and biological properties along with conserving capacity of the moisture holding capacity of soil and this, resulting in enhanced crop productivity along with maintain the quality of crop produce [5].

Vermicomposts are organic materials broken down by interactions between microorganism and earthworms in a mesophilic process (up to 25°C), to produce fully stabilized organic soil amendments with low C: N ratios. They have a high and diverse microbial and enzymatic activity, fine particulate structure, good moisture-holding capacity, and contain nutrients such as N, P, K, Ca and Mg in forms readily taken up by plants [6].

Integrated use of inorganic fertilizers with organic manures is a sustainable approach for efficient nutrient usage which enhances efficiency of the chemical fertilizers while reducing nutrient losses [7].

2. MATERIALS AND METHODS

2.1 Site Description and Treatments

The field experiment was conducted during Rabi season 2021-2022 at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.). Geographically, this region falls under sub-tropical climate and it is situated at 24.4^{o} - 26.56^{o} N latitude, 82.12^{o} E longitude and at an Indo-gangetic alluvial of eastern Uttar Pradesh in India. The annual rainfall of this region is about 1100 mm in which 85 per cent received during monsoon (mid June to end of September). The winter month are cold and dry and occasional frost occurring during the period. The experiment was laid out in randomized block design and replicated thrice. Following treatments were used in this experiment.

Symbol	Treatment
T1	Control (Unfertilized)
T2	100 % RDF (120:60:50)
T3	80% RDF + 20% N-Vermicompost (VC) + Mycorrhizae
T4	80% RDF + 20% N-Poultry Manure (PM) + Mycorrhizae
T5	60 % RDF + 40% N-Vermicompost (VC) + Mycorrhizae
T6	60% RDF + 40% N-Poultry Manure (PM) + Mycorrhizae
T7	60% RDF + 20% N –Vermicompost (VC) + 20% N-Poultry Manure (PM) + Mycorrhizae
T8	50% N-Vermicompost (VC) + 50% N -Poultry manure (PM) + Mycorrhizae

2.2 Soil Properties Determinations

Soil samples (0-30 cm) were collected from different sites of the experimental site and mixed properly to make a composite sample to assess its physico-chemical properties. The following soil parameters were determined after air drying and grinding after passing through a 2-mm screen: (i) soil bulk density (ii) soil particle density (iii) soil porosity (iv) soil pH (v) electrical conductivity (vi) soil organic carbon (vii) available N, P, K.

2.3 Plant height

Five plants were selected randomly from each plot and tagged. The height was measured in cm with the help of meter scale from the base of the plant to top of the plant and mean value was computed at 30,60,90 DAS and at harvest.

2.4 Leaf Area Index

The leaf area of five plants was measured by automatic leaf area meter at 30, 60 and 90 days after sowing of the crop. Leaf area index was calculated by the formula.

Leaf area index = leaf area / ground area.

2.5 Dry Matter Accumulations (kg ha^{-1})

At harvest, five plants were randomly selected from border area of each plot. Plant samples were cleaned and chopped then put separately in perforated paper bags and allow for over dry at 65^{o}C until all the moisture in the plants was escaped. At last weighed the constant dry weight and expressed in gram plant^{-1} then multiplied with total number of plants in a hectare.

2.6 Statistic Analysis

Data collected were subjected to statistical analysis by using a computer program OPSTAT. Least Significant Difference test (LSD) at 5% probability level was applied to compare the differences among treatments means.

Table 1. Physico - chemical properties of soil before experiment

	Soil Properties	Values in 2021	Method of determination
1.	Sand (%)	24.4	Hydrometer (Bouyocos, 1962)
2.	Silt (%)	51.5	
3.	Clay (%)	24.1	
4.	Textural class	Silt loam	Triangular method (Lyon *et al*., 1952)
5.	Soil bulk density (g/cc)	1.40	Core method (Jackson, 1973)
6.	Soil pH (1:2.5)	8.14	Glass electrode pH meter (Jackson, 1973)
7.	Electrical Conductivity (1:2.5) (dSm^{-1})	0.34	Electrical conductivity meter (Jackson, 1973)
8.	Organic carbon (%)	0.45	Rapid titration method (Walkley and Black, 1934)
9.	Available N (kg ha^{-1})	157	Alkaline permanganate method (Subbiah and Asija, 1956)
10.	Available P (kg ha^{-1})	15.16	Olsen's method (Olsen *et al*., 1954)
11.	Available K (kg ha^{-1})	228	Flame photometer (Jackson, 1973)

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

Growth parameters viz., plant height, leaf area index and dry matter accumulation of maize varied significantly with different treatment combinations.

3.1.1 Plant height

Plant height (69.5, 179.7 and 204.1 cm at 30, 60 and 90 DAS, respectively) was recorded maximum under application of 60% RDF + 40% N-Poultry Manure (PM) + Mycorrhizae (Table 2). The beneficial effect of poultry manure might be due to the elevated supply of higher amount of both macro and micronutrient particularly nitrogen that helped in rapid cell division and cell elongation. These results are in consonance with the conclusions of Farhad et al. [8] and Almaz et al. [9].

3.1.2 Dry matter accumulation

The maximum dry matter accumulation (723, 6910 and 14889 kg ha^{-1} at 30, 60 and 90 DAS respectively) was recorded maximum under application of 60% RDF + 40% N-Poultry Manure (PM) + Mycorrhizae (Table 3). The highest dry matter accumulation was recorded under 60% RDF + 40% N-Poultry Manure (PM) + Mycorrhizae followed by application of 60% RDF + 20% N -Vermicompost (VC) + 20% N-Poultry Manure (PM) + Mycorrhizae. The increase in dry matter accumulation under treatment T_6 might be due to slow release of nutrients with the application of poultry manure which enabled the leaf area duration to extend and provided an opportunity for the plants to increase the photosynthetic rate leading to the higher accumulation of dry matter. The similar result was earlier reported by B. Sandhya Rani et al. [10] and Sahoo et al. [11].

3.1.3 Leaf area index

The maximal leaf area index (1.46, 5.47 and 4.79 at 30, 60 and 90 days respectively) was observed under application of 60% RDF + 40% N-Poultry Manure (PM) + Mycorrhizae followed by application of 60% RDF + 20% N - Vermicompost (VC) + 20% N-Poultry Manure (PM) + Mycorrhizae (Table 4). The congenial response of poultry manure is due to increased uptake of nitrogen which being the constituent of protoplasm and protein, induced the vegetative growth of the plant. In the present study also, better utilization of nitrogen resulted in higher leaf surface area and there by higher LAI. This result is in conformity with earlier determinations of Mahmood et al. [12] and Berdjour et al. [13] who reported similar finding in maize.

3.2 Yield Attributes

Yield parameters viz., cob length, cob weight, number of grain rows/cob, number of grains/row, number of grains/cob and test weight of maize varied significantly with different treatment combinations.

It is apparent from the Table 5 that application of 60% RDF + 40% N-Poultry Manure (PM) + mycorrhizae recorded maximum cob length (17.74 cm), cob weight (232.45 g), number of grain rows/cob (16.0), number of grains/row (29.94), number of grains/cob (452.31) and test

Table 2. Synergistic effect of organic manure and mycorrhizae on plant height (cm) of maize at different crop growth stages

Treatments		Plant height (cm)		
		30 DAS	60 DAS	90 DAS
T_1	Control (Unfertilized)	54.32	142.16	168.31
T_2	100 % RDF (120:60:50)	58.83	159.24	182.16
T_3	80% RDF + 20% N- (VC) + Mycorrhizae	59.40	162.14	186.38
T_4	80% RDF + 20% N- (PM) + Mycorrhizae	61.86	165.36	190.53
T_5	60 % RDF + 40% N- (VC) + Mycorrhizae	65.26	169.31	193.32
T_6	60% RDF + 40% N- (PM) + Mycorrhizae	69.58	179.76	204.13
T_7	60% RDF + 20% N- (VC) + 20% N- (PM) + Mycorrhizae	67.72	173.33	198.43
T_8	50% N- (VC) + 50% N- (PM)+ Mycorrhizae	57.43	155.13	178.16
SEm±		0.65	2.38	3.12
CD (p=0.05)		2.01	7.31	9.57

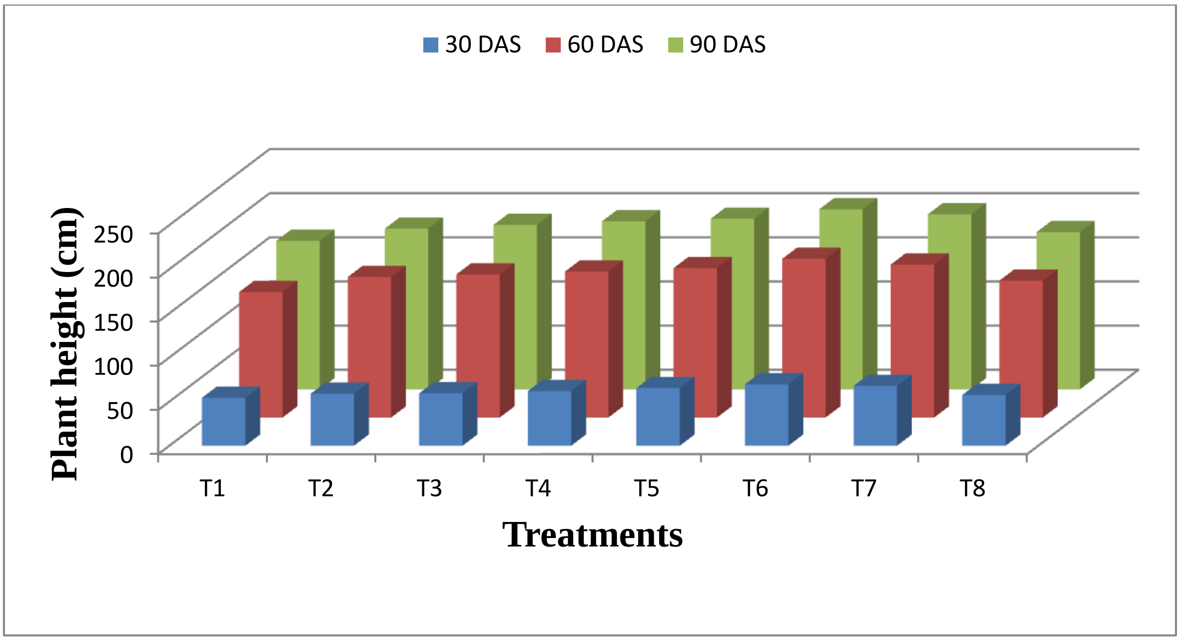

Fig. 1. Synergistic effect of organic manure and mycorrhizae on plant height (cm) of maize at different crop growth stages

Table 3. Synergistic effect of different organic manure and mycorrhizae on dry matter accumulation (kg ha^{-1}) of maize at different crop growth

Treatments		Dry matter accumulation (kg ha^{-1})		
		30 DAS	**60 DAS**	**90 DAS**
T_1	Control (Unfertilized)	485	4769	11927
T_2	100 % RDF (120:60:50)	538	5442	12704
T_3	80% RDF + 20% N- (VC) + Mycorrhizae	578	5716	13109
T_4	80% RDF + 20% N- (PM) + Mycorrhizae	598	6172	13323
T_5	60 % RDF + 40% N- (VC) + Mycorrhizae	608	6312	13854
T_6	60% RDF + 40% N- (PM) + Mycorrhizae	723	6910	14889
T_7	60% RDF + 20% N- (VC) + 20% N-(PM) + Mycorrhizae	697	6693	14410
T_8	50% N- (VC) + 50% N- (PM) + Mycorrhizae	506	5226	12490
SEm±		8.75	76.01	239.39
CD (p=0.05)		26.82	232.81	733.15

weight (220.83 g) followed by application of 60% RDF + 20% N -Vermicompost (VC) + 20% N-Poultry Manure (PM) + Mycorrhizae. Significantly higher cob length, cob weight, number of grains/row, test weight, number of grain rows/cob and number of grains/cob was obtained under treatment T_6 followed by T_7 treatment. This increase in yield attributes might be due to higher availability of all the nutrients from poultry manure and increased translocation of all nutrients up to cob formation and the resultant uptake of nutrients. Increase in yield attributes under treatment 60% RDF + 40% Nitrogen through poultry manure and mycorrhizae was as a result of improved photosynthates translocation from source to sink and better absorption of all nutrients in hybrid maize. The result is in accordance with earlier conclusions of Mukhtar et al. [14] and Akintoye and Olaniyan [15].

3.3 Yield

It is apparent from the Table 6 and Fig. 5 that application of 60% RDF + 40% N-Poultry Manure (PM) + mycorrhizae recorded maximum grain yield (39.83 q ha^{-1}), stover yield (65.71 q ha^{-1}) and biological yield (105.56 q ha^{-1}) followed by application of 60% RDF + 20% N -Vermicompost (VC) + 20% N-Poultry Manure (PM) +

Mycorrhizae. Grain and stover yield of crop is significantly influenced by the application of poultry manure and mycorrhizae along with chemical fertilizer. The increase in yield under treatment T_6 is due to the efficient consumption of nutrients supplied by poultry manure along with inorganic fertilizers to maize as reported by Yilmaz et al. [4]. The combined application of poultry manure and inorganic fertilizers produced the synergistic effect on yield and yield attributes. Ayoola and Makinde [16] and [17] reported higher maize yield from combined use of NPK fertilizer and poultry manure than from sole inorganic fertilizer applications. The similar finding was earlier reported by Shiyam et al. [18] and Udom et al. [19].

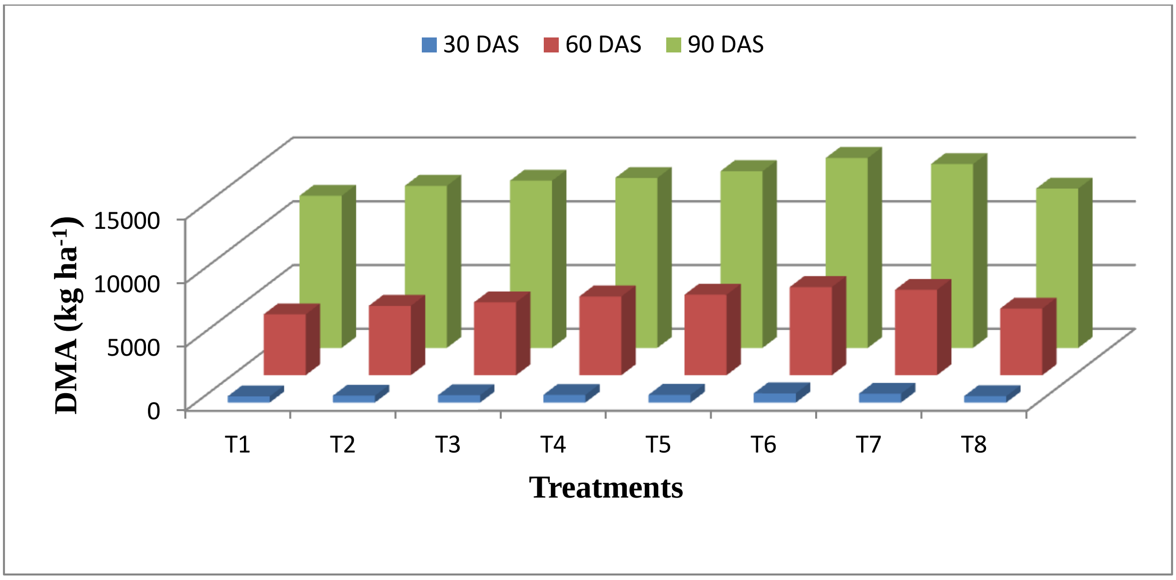

Fig 2. Synergistic effect of different organic manure and mycorrhizae on dry matter accumulation (kg ha^{-1}) of maize at different crop growth

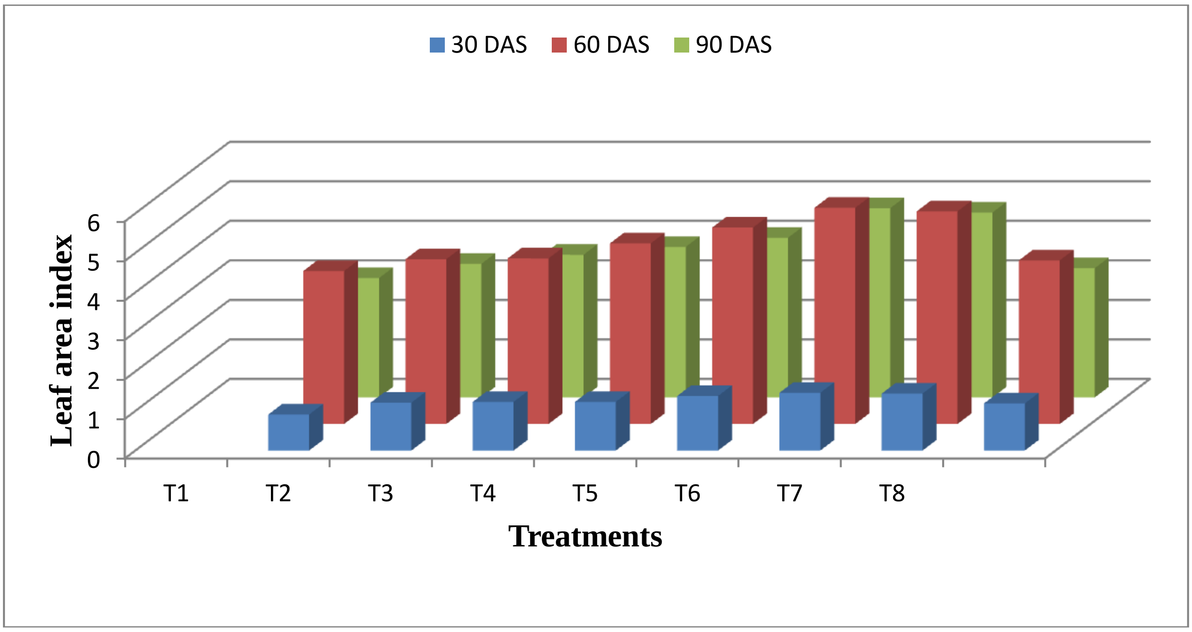

Fig. 3. Synergistic effect of different organic manure and mycorrhizae on leaf area index of maize at different crop growth

Table 4. Synergistic effect of different organic manure and mycorrhizae on leaf area index of maize at different crop growth

Treatments		Leaf Area Index		
		30 DAS	60 DAS	90 DAS
T_1	Control (Unfertilized)	0.91	3.87	3.02
T_2	100 % RDF (120:60:50)	1.21	4.17	3.38
T_3	80% RDF + 20% N- (VC) + Mycorrhizae	1.23	4.19	3.61
T_4	80% RDF + 20% N- (PM) + Mycorrhizae	1.23	4.57	3.81
T_5	60 % RDF + 40% N- (VC) + Mycorrhizae	1.38	4.97	4.04
T_6	60% RDF + 40% N- (PM) + Mycorrhizae	1.46	5.47	4.79
T_7	60% RDF + 20% N- (VC) + 20% N- (PM) + Mycorrhizae	1.44	5.38	4.68
T_8	50% N- (VC) + 50% N- (PM) + Mycorrhizae	1.19	4.14	3.27
SEm±		0.01	0.07	0.06
CD (p=0.05)		0.05	0. 21	0. 19

Table 5. Synergistic effect of organic manure and mycorrhizae on yield attributes of maize

Treatments		Cob Length (cm)	No. of grain rows cob^{-1}	No. of grains row^{-1}	No. of grains cob^{-1}	Test weight (g)	Weight of cob (g)
T_1	Control (Unfertilized)	11.10	11.60	18.34	202.48	150.12	202.36
T_2	100 % RDF (120:60:50)	14.41	13.60	26.36	354.25	170.12	209.13
T_3	80% RDF + 20% N- (VC) + Mycorrhizae	14.65	14.40	27.00	363.52	171.18	214.67
T_4	80% RDF + 20% N- (PM) + Mycorrhizae	15.49	14.40	27.54	371.23	181.53	215.80
T_5	60 % RDF + 40% N- (VC) + Mycorrhizae	16.12	15.20	27.86	389.61	192.32	217.14
T_6	60% RDF + 40% N- (PM) + Mycorrhizae	17.74	16.00	29.94	452.31	220.83	232.45
T_7	60% RDF + 20% N- (VC) + 20% N- (PM) + Mycorrhizae	17.46	15.60	28.97	436.36	210.16	225.38
T_8	50% N- (VC) + 50% N- (PM) + Mycorrhizae	13.62	13.20	26.02	341.38	169.14	207.23
SEm±		0.23	0.15	0.31	5.70	3.53	2.81
CD (p=0.05)		0.72	0.47	0.98	17.46	10.81	8.48

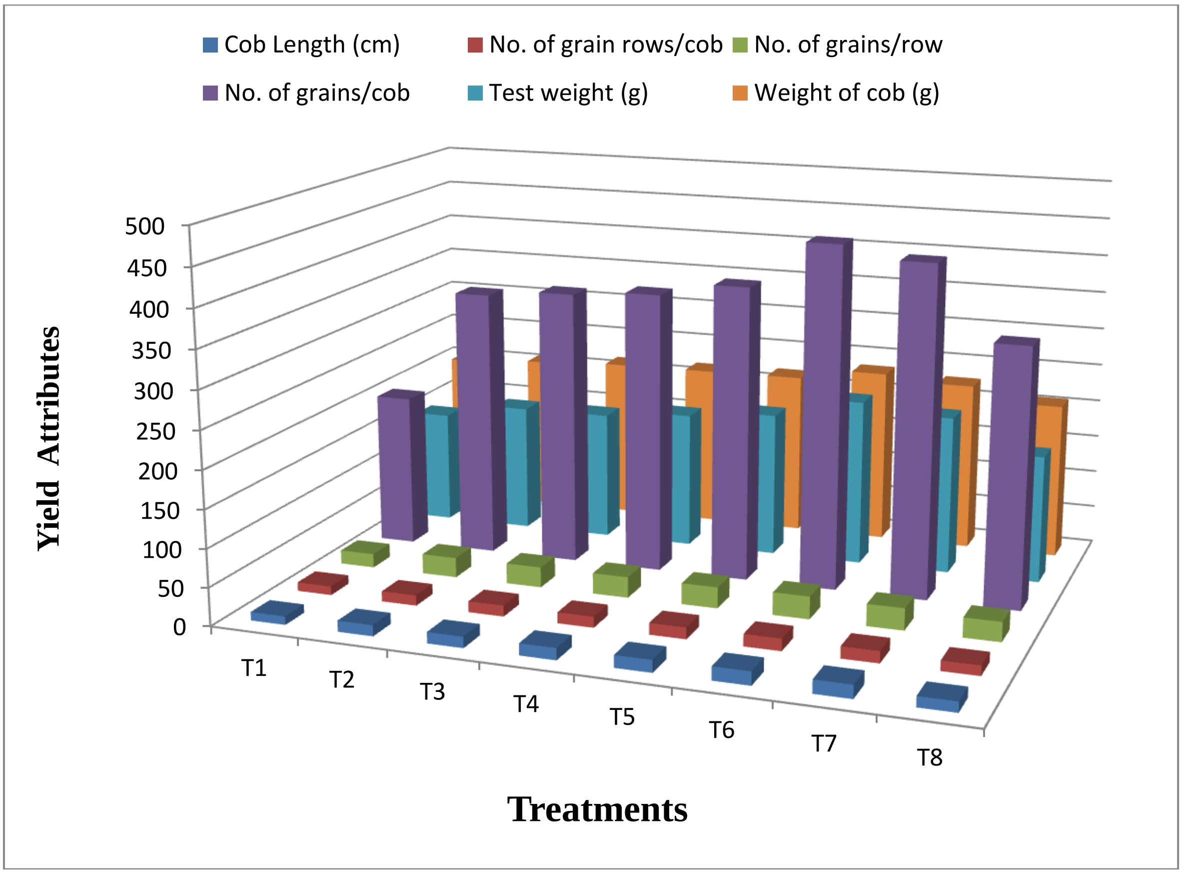

Fig. 4. Synergistic effect of organic manure and mycorrhizae on yield attributes of maize

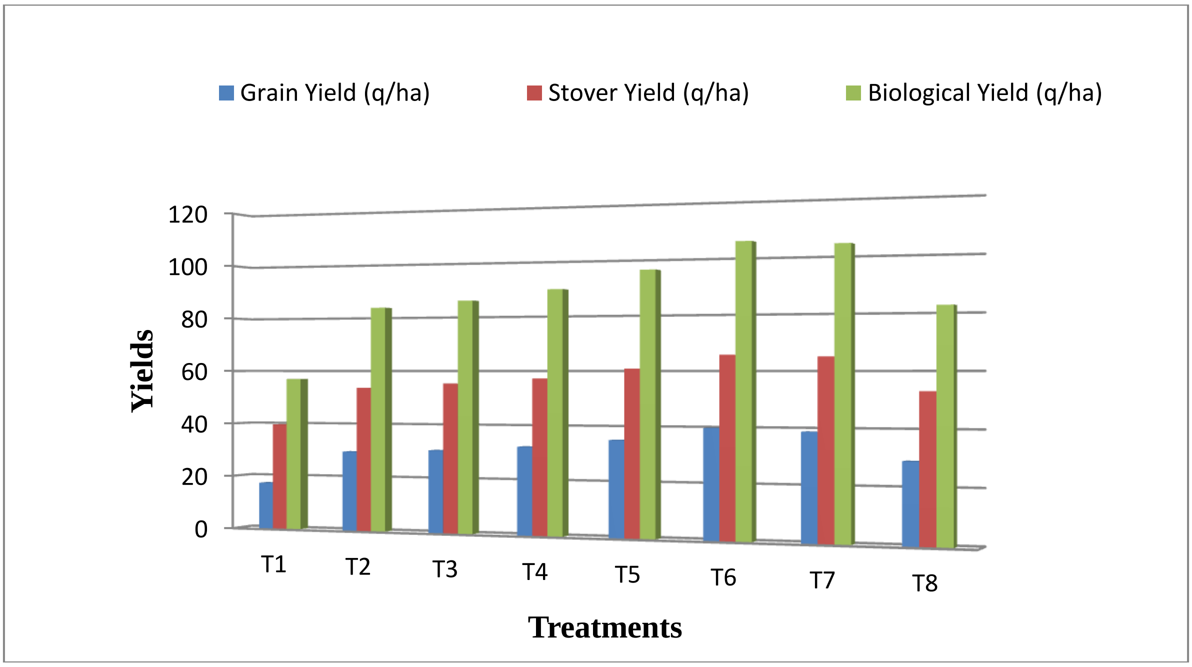

Fig. 5. Synergistic effect of organic manure and mycorrhizae on yield of maize

Table 6. Synergistic effect of organic manure and mycorrhizae on yield of maize

Treatments		Grain Yield (q ha^{-1})	Stover Yield (q ha^{-1})	Biological Yield (q ha^{-1})
T_1	Control (Unfertilized)	17.28	39.61	56.92
T_2	100 % RDF (120:60:50)	29.64	53.64	83.63
T_3	80% RDF + 20% N- (VC) + Mycorrhizae	30.57	55.32	85.89
T_4	80% RDF + 20% N- (PM) + Mycorrhizae	32.36	57.24	89.63
T_5	60 % RDF + 40% N- (VC) + Mycorrhizae	35.18	60.86	96.14
T_6	60% RDF + 40% N- (PM) + Mycorrhizae	39.83	65.71	105.56
T_7	60% RDF + 20% N- (VC) + 20% N- (PM) + Mycorrhizae	38.86	65.04	104.11
T_8	50% N- (VC) + 50% N- (PM) + Mycorrhizae	29.14	53.10	82.47
SEm±		0.42	0.36	0.94
CD (p=0.05)		1.31	1.11	2.88

4. CONCLUSION

The study revealed that the synergism of different organic manure and mycorrhizae along with inorganic fertilizers generally improved the soil physical properties (bulk density, porosity and water holding capacity) and chemical properties (soil organic carbon, pH, soil available nitrogen, phosphorus and potassium) which help in the growth and productivity of maize crop. Application of 60% RDF + 40% N- PM + Mycorrhizae significantly improve growth attributes, yield attributes and yield of the maize crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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