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Effect of organic and inorganic sources on soil properties, yield and growth of spring maize (*Zea mays* L.)

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Abstract

A field experiment entitled was conduct under title as, "Effect of organic and inorganic sources on soil properties, yield and growth of spring maize (*Zea mays* L.)" at Research and Advance Studies Farm, Department of Agricultural Sciences, Sant Baba Bhag Singh University, Khiala, Jalandhar during spring 2023. The field experiment was designed in Randomized Block Design, with 7 treatments and 3 replications. The field experiment was designed to study the influence of biofertilizer on soil properties, yield and growth of maize.

It was observed that treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P) shows the superior after 90 DAS under growth parameters (plant height 160.6 cm, number of leaves 11.1, LAI 5.42) but it was statistically similar with the treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P). T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produced maximum grain yield of 61.5 q ha^{-1}. Similar results was observed for the number of cobs per plant, number of grains per cob, 1000-grain weight, cob length, cob girth, stover yield, etc. So, it was observed that growth parameters, grain yield and yield attributes was significantly increased with applications of biofertilizers. On the other hand applications of biofertilizer increase the available nutrients status in soil, but there is no significant effect on soil organic carbon percentage.

Keywords: Biofertilizers applications, soil properties, growth parameters, yield parameters

Introduction

Maize, scientifically known as *Zea mays* L, is an emerging crop renowned for its remarkable adaptability to diverse agro-climatic conditions. It holds the esteemed title of the "queen of cereals" globally, primarily due to its exceptional productivity potential, ranking third after wheat and rice. The demand for maize grains is continuously escalating, driven by factors like population growth and economic development. Consequently, maize plays a crucial role as a staple crop worldwide, catering to the increasing needs of food, animal feed, and various industries [1].

According to FAOStat, 2021, the total area of maize grown for dry grain is around 197 M hectares [3]. According to estimates from the International Grain Council, maize output is anticipated to reach 1178.6 million tonnes in 2022–2023 while demand is anticipated to continue at 1196.8 million tonnes for food, feed, and industrial use [4]. Recently, the FAO increased the overall area under global cereal production by 7.7 million tonnes (0.3 percent), bringing it to 2 785 million tonnes. The estimated worldwide production of coarse grains in 2023 is 1467 m t. With a total of 1.2 billion tonnes produced globally in 2020 (FAO 2022), maize output is around 12 percent [5]. The output of maize in the world increased by 31% in the United States, with China coming in second and Brazil third. By 2050, there will be 9.7 billion people on the planet (or 8.9 to 10.7 billion depending on expected growth rates; UN-DESA, 2019), a growth of 2 billion above the present 7.7 billion [6].

The ability to grow healthy crops depends on the condition of the soil. To boost the microbial biomass and soil enzymatic activity, the right proportion of organic and inorganic manures is needed [10]. It is vital to employ ecologically friendly fertilisers, such as bio fertilisers, because the continual use of chemical-based fertilisers is ineffective at promoting the development of healthy soil (Fitriatin *et al*., 2020) [11].

Bacteria that can dissolve phosphorus and fixed nitrogen, as well as supply macronutrients and break down organic materials, make up the native soil microorganisms. When applied to seeds, plant surfaces, or soil, bio fertilisers are compounds that include living organisms that colonise the rhizosphere or interior of plants and promote plant development through boosting the accessibility of primary nutrients and/or encouraging specific development in plants (Fitriatin *et al.*, 2020) [11]. The prolonged usage of chemical fertilisers without balancing it through the addition of organic matter can lead to significant challenges while having an effect on soil deterioration. Utilising ecologically friendly fertilisers, such as bio fertilisers, can assist improve the health of the soil and supply micronutrients that are unavailable to plants as a different approach to this issue [11]. Bio fertilisers can increase soil fertility, fertilisation effectiveness, and the condition of the soil. Increased food availability and maintenance of the nutritional N cycle are crucial functions of bacteria in the root system environment. To boost the population of nitrogen-fixing bacteria in the rhizosphere environment, which is anticipated to enhance soil nutrients, one method is to inject bio fertilisers made of nitrogen-fixing bacteria. The usage of bio fertilisers will not leave residues on crop yields, making them safe for both the ecosystem and the health of people [11].

Plant growth and yield are increased by using bio fertilisers. The bacteria that solubilize phosphate increase phosphatase activity, plant development, and maize production (Fitriatin *et al*., 2020) [11]. The greatest microbial diversity was seen in soil treated with organic and NPK fertilisers. A less expensive, less costly to operate, and environmentally benign way to increase agricultural output is through a combined application of biofertilizers. *Azotobacter* is an autonomous, aerobic, diazotrophic bacterium that is typically found in soil and has the capacity to utilise N2 as the only source of nitrogen. The most prevalent organisms in Indian soil, among other species, are *Azotobacter chrococcum*. Approximately 33 percent of the studies using *Azotobacter* inoculation on crops were carried out in India and showed positive responses [12].

Therefore, the goal of this study is to identify the best application technique that promotes maize development and production. It also aims to find the best treatment that may be used on the maize crop to produce a high yield of high-quality maize. The current study's objective is to assess the effectiveness of using PSB in liquid form and soil application of *Azotobacter* in conjunction with nitrogen and phosphate fertiliser to grow maize.

Materials and Methods

The research experiment was conducted under title as, "Effect of organic and inorganic sources on soil properties, yield and growth of spring maize (*Zea mays* L.)" carried out at Main Agricultural Research Field, Department of Agriculture, Sant Baba Bhag Singh University, Khiala, Jalandhar during spring 2023. The experiment was conducted in Randomized Block Design (RBD) with three replications at the experimental Farm of main Agricultural Research Field, SBBSU, Punjab. The plot size for each treatment was 2.6 m x 4.7 m. The seeds of crop were placed manually in the ridges at a plant to plant distance of 20 cm with a seed rate of 10 kg/ha and sown on 13 February 2023, while harvested on 6th June 2023.

Table 1: Soil physical and chemical properties of experimental field

Sr. No.	Particulars	Soil Depth (0-15cm depth)
I Physical properties		
1	Sand (%)	81.6
2	Silt (%)	10.7
3	Clay (%)	7.7
II Chemical properties		
1	pH (1:2)	7.1
2	Electrical conductivity (dS/m)	0.20
3	Organic Carbon (%)	0.30
III Available nutrient status		
1	Available N (kg ha^{-1})	140.2
2	Available P (kg ha^{-1})	17.5
3	Available K (kg ha^{-1})	90.6

Table 2: Treatment Details

T_1	Control
T_2	Seed treatment with 120 ml of PSB + 100% N and P
T_3	Soil application of 200 g *Azotobacter* + FYM + 100% N and P
T_4	Seed treatment with 160 ml of PSB + 100% N and P
T_5	Soil application of 350 g *Azotobacter* + FYM + 100% N and P
T_6	Seed treatment with 220 ml of PSB + 100% N and P
T_7	Soil application of 450 g *Azotobacter* + FYM + 100% N and P

Results and Discussion

The data recorded on different parameters of maize crop are discussed in this chapter under the following heads:

Growth Attributes

Seed germination percentage (%)

Seed germination percentage was increased with the application of biofertilizer along with inorganic fertilizer. The maximum seed germination percentage 99.4% was found under T_4 (Seed treatment with 160 ml of PSB + 100% N and P) and followed by T_6 (Seed treatment with 220 ml of PSB + 100% N and P) was 94.1%. The minimum seed germination percentage 51.8% were found under treatment T_1 (Control) and 58.7% under T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P. This is in conformity with the results of Umesha *et al.* 2014 [16] who observed such increased germination due to biofertilizers application. Babu *et al.*, 2017 [27] results also supported.

Plant height

The maximum plant height was observed with T_4 treatment (Seed treatment with 160 ml of PSB + 100% N and P) as 160.6 cm at 90 DAS respectively which in terms of statistics, was comparable to the T_6 treatment (Seed treatment with 220 ml of PSB + 100% N and P) and also significantly higher than the other biofertilizer application. The lowest plant height was observed in T_1 treatment (Control Plot) as 122.4 cm at 90 DAS as compared to other treatments. *Azotobacter*, a bacterium fixes N from the air, which is subsequently fixed in the soil, and produces phytohormones in the root zone of plants that can boost plant growth and production. The increase in is what causes plants to grow to their maximum height [11]. Fitriatin *et al.*, 2021 [11] stated that seed treatment and soil application of biofertilizer increase the plant height.

Number of leaves per plant

The data indicates that the number of leaves per plant increased with different biofertilizers application. The T_4 treatment (Seed treatment with 160 ml of PSB + 100% N and P) recorded the maximum number of leaves per plant at 90 DAS, as 11.1 respectively, which was statistically at par with the T_6 (Seed treatment with 220 ml of PSB + 100% N and P) which was statistically higher than other treatment. The lowest number of leaves per plant was recorded in T_1 treatment (Control Plot) as 8.1 after 90 DAS as compared to other treatment. Purwani *et al.*, 2020 [31] also state that combination of chemical fertilizers and biofertilizer produced higher number of leaf than control treatment.

Leaf area index (LAI)

The maximum LAI recorded after 90 DAS was under treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P) as 5.42 respectively, which was statistically at par with T_6 (Seed treatment with 220 ml of PSB + 100% N and P) but also significantly higher than the other treatment. Kouchebagh *et al.*, 2012 [23] revealed that interaction of seed inoculation (Biofertilizer *Pseudomonas*, *Azospirillum* and *Azotobacter*) and N fertilization could increase crop LAI (44%) significantly, as compared to non treated ones.

Table 3: Effect of different biofertilizer applications on Germination percentage, Plant height, Number of leaves per plant and Leaf area index

Treatments	Mean			
	Germination percentage	Plant height (cm)	Number of Leaves per plant	Leaf Area Index (LAI)
T_1	51.8	122.4	8.1	3.37
T_2	74.6	150.6	9.9	4.97
T_3	58.7	144.3	10.1	4.78
T_4	99.4	160.6	11.1	5.42
T_5	75.6	153.9	10.2	5.38
T_6	94.1	157.4	10.3	5.40
T_7	76.1	148.3	10.1	4.92
CD(p=0.05)	NS	5.25	1.13	1.21

Crop phenology

Days taken to 50% tasselling

The maximum numbers of days taken for 50% of tasselling is under T_1 (Control Plot) as 75.7 days. This treatment combination has no biofertilizer application and it was significantly more as compared to all other biofertilizer level combinations. The minimum number of days taken to 50% tasselling were recorded under treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P) as 72.5 days.

Days taken to 50% silking

The maximum number of days taken for 50% silking is under treatment T_1 (Control Plot) as 78.5 days and minimum number of days taken to 50% silking were recorded under treatment T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P) as 75.1 days. Taipodia *et al.*, 2013 [85] seed inoculation with PSB along with 5t FYM ha^{-1} has taken less number of days to 50% of silking as compared control where no use of biofertilizer with FYM.

Days taken to physiological maturity

The treatment T_1 (Control Plot) has taken significantly maximum number of 113 days to reach the stage of physiologically maturity which was at par with the treatment. The shortest period of days was 104 days for physiological maturity was under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P). Latha *et al.*, 2018 [83] and Soleymanifard *et al.*, 2013 [81] also observed the similar result.

Yield attributes

Number of cobs per plant

The treatment T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P) has significantly highest number of cobs per plant as mean value 1.07 as compared to treatment T_1 (Control Plot). The minimum number of cobs 0.68 per plant was discovered under treatment T_1 (Control Plot). Similar result was also reported by Taipodia *et al.*, 2013 [85] and Choudhary *et al.*, 2012 [73].

Number of grains per cob

The maximum number of grains 499.2 per cob was observed as under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) which were at par with the treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P) and significantly higher as compared to other treatments. Umesha *et al.*, 2014 [16] observed that the higher number of grains per cob founded due to positive effect of biofertilizer.

1000-grain weight

The treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produces maximum 1000-grains weight of 342.0 g and minimum 1000-grain weight of 233.5 g was observed under treatment T_1 (Control plot). Similar results were reported by Naseri *et al.*, 2013 [36] and Taipodia *et al.*, 2013 [85].

Cob length

The maximum cob length 18.7 cm was observed under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) which was at par treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P) and significantly higher as compared to other treatments. Minimum cob length of 15.2 cm was found under treatment T_1 (Control plot). The results are conformity with finding of Umesha *et al.*, 2014 [16] and Rina *et al.*, 2020 [44].

Table 4: Effect of different biofertilizer applications on Days taken to tasselling, Days taken to silking, Days taken to physiological maturity, Number of cobs per plant, Number of grains per plant, 1000-grain weight (g), Cob length, Cob girth, Number of grain rows per cob

Treatments	Mean								
	Crop Phenology			Yield attributes					
	Days taken to tasselling	Days taken to silking	Days taken to physiological maturity	Number of cobs per plant	Number of grains per cob	1000-grain weight (g)	Cob length (cm)	Cob girth (cm)	Number of grain rows per cob
T_1	75.7	78.5	113.0	0.68	304.4	233.5	15.2	12.2	11.9
T_2	73.5	76.4	108.8	0.94	363.1	250.8	17.5	14.8	13.6
T_3	73.8	75.6	109.3	1.07	419.6	261.0	16.8	14.7	14.5
T_4	72.5	75.1	107.3	1.00	411.4	252.5	17.8	16.2	14.6
T_5	73.6	76.8	107.1	0.89	447.9	270.1	18.4	15.8	14.1
T_6	74.3	76.2	104.3	0.84	456.0	322.4	18.5	16.1	15.1
T_7	73.3	75.2	104.0	1.04	499.2	342.0	18.7	16.4	15.3
CD(p=0.05)	0.572	0.654	2.00	0.242	3.493	2.757	1.80	1.15	0.76

Cob girth

The maximum cob girth 16.4 cm was observed under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) which were statistically at par with the treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P), T_6 (Seed treatment with 220 ml of PSB + 100% N and P) where cob girth was 16.2, 16.1 cm and significantly higher as compared to other treatments. Minimum cob girth was found as 12.2 cm under treatment T_1 (Control plot). Similar positive results are found by Taipodia *et al.*, 2013 [85] and Latha *et al.*, 2018 [83].

Number of grain rows per cob

The maximum number of grain rows 15.3 per cob was observed under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) and Minimum number of grain rows per cob was observed as 11.9 under treatment T_1 (Control). The results of Naseri *et al.*, 2013 [36] are also supported.

Grain yield

The treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produces maximum grain yield of 61.5 q ha^{-1}. Minimum grain yield of 27.1 q ha^{-1} was recorded under treatment T_1 (Control Plot). Meena *et al.*, 2013 [12] also observed that combine application of inorganic fertilizers, FYM and Azotobacter inoculation produced high maize yield.

Stover yield

The maximum stover yield 148.9 q ha^{-1} was recorded under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) which was statistically at par with the treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P) but significantly higher as compared to other treatments. Minimum stover yield of 82.3 q ha^{-1} was recorded under treatment T_1 (Control Plot). Rina *et al.*, 2020 [44] and Singh L *et al.*, 2017 [54] also reported about increased of stover yield with the application of biofertilizers.

Table 5: Effect of different biofertilizer applications on Grain yield, Stover yield, Shelling %, Harvesting index (%)

Treatments	Means			
	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Shelling (%)	Harvesting Index (%)
T_1	27.1	82.3	55.9	24.0
T_2	41.1	101.9	70.0	27.1
T_3	42.1	124.6	68.6	25.8
T_4	53.8	137.6	74.6	28.1
T_5	47.7	134.7	84.4	26.6
T_6	57.3	144.2	76.3	28.4
T_7	61.5	148.9	86.7	29.1
CD(p=0.05)	6.59	7.25	1.938	2.15

Shelling %

The maximum shelling percentage (86.7%) was under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) and Minimum shelling percentage was observed as 55.9% under treatment T_1 (Control Plot). Singh L *et al.*, 2017 [54] also observed higher shelling percentage obtain with the combine application of organic and inorganic fertilizers.

Harvesting index

The maximum harvesting index of 29.1% was recorded under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) and the minimum harvesting index 24.0% was observed in treatment T_1 (Control Plot). Naserirad *et al.*, 2011 [22] also found that maximum harvesting index because usage of bio-fertilizers increased the harvest index through affecting dry weight and assigning more photosynthetic matter to grain.

Chemical properties of soil

Soil pH

The maximum pH were discovered in treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) 7.8 and the minimum value of pH was discovered in treatment T_1 (Control Plot), but it was at par treatment T_2 (Seed treatment with 120 ml of PSB + 100% N and P). Taipodia *et al.*, 2013 [85] also found that biofertilizer application had significant impact on soil pH.

Soil electrical conductivity (dSm^{-1})

The maximum electrical conductivity were observed in treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) 0.24 dSm^{-1} which was at par with T_2 (Seed treatment with 120 ml of PSB + 100% N and P). The minimum electrical conductivity was found in treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P) 0.10. Similar finding was observed by Manohar *et al.*, 2021 [64].

Soil organic carbon (%)

The maximum organic carbon (%) were found in treatment T_1 (Control Plot) 0.40% which was statistically at par with treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P) 0.39%. The minimum organic carbon (%) were found in treatment T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P) 0.22%. The results of Manohar *et al.*, 2021 [64] and Ahmad *et al.*, 2013 [60] were also supported.

Available nutrients status of soil

Available Nitrogen (Kg ha^{-1})

The maximum values of available N were found in treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) 196 kg ha^{-1}. The minimum values of available N were found in treatment T_1 (Control Plot) and T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P) were 154, 158 kg ha^{-1} respectively. Ahmad *et al.*, 2013 [60] also found that available N were increases with the applications of biofertilizers along with chemical fertilizers.

Available Phosphorous (Kg ha^{-1})

The maximum values of available P were found in treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) 27.68 kg ha^{-1}, which was significantly at par with treatment T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P) and T_5 (Soil application of 350 g *Azotobacter* + FYM + 100% N and P). The minimum values of available P were found in treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P) and T_1 (Control Plot) were 16.91, 17.22 kg ha^{-1} respectively. Manohar *et al.*, 2021 [64] found the similar results because bio-fertilizers effectively solubilise native phosphorus (P) in the soil by releasing a variety of organic acids.

Available Potassium (Kg ha^{-1})

The highest value of available K observed with treatment T_5 (Soil application of 350 g *Azotobacter* + FYM + 100% N and P) 122.12 kg ha^{-1} which was at par with treatment T_4 and T_7 respectively. The lowest value of available K observed with treatment T_3 (Soil application of 200 g *Azotobacter* + FYM + 100% N and P). Manohar *et al.*, 2021 [64] found the similar results. Similar results were also found by Ahmad *et al.*, 2013 [60].

Table 6: Effect of different biofertilizer applications on Chemical properties and Available nutrients status of soil

Treatments	Mean					
	Chemical properties			Available nutrients		
	pH (1:2)	Electrical conductivity (dSm^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	7.2	0.20	0.40	154	17.22	92.35
T_2	7.3	0.22	0.37	167	20.78	89.04
T_3	7.4	0.18	0.22	158	27.05	78.82
T_4	7.7	0.12	0.39	179	18.00	105.79
T_5	7.5	0.14	0.34	192	26.52	122.12
T_6	7.6	0.10	0.32	174	16.91	79.25
T_7	7.8	0.24	0.36	196	27.68	105.77
CD (p=0.05)	NS	NS	0.02	1.04	0.79	1.249

Economic Analysis

Gross returns

The maximum gross returns of Rs. 128535 ha^{-1} is found under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P). The minimum gross return is Rs. 56639 ha^{-1} under treatment T_1 (Control Plot), because of no application of organic and inorganic fertilizers. Similarly, Singh *et al.*, 2019 [75] found significantly increase of gross returns with combine use of organic and inorganic fertilizers.

Net returns

The treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produces maximum net returns of Rs.79981 ha^{-1}, but it was at par with the treatment T_6 (Seed treatment with 220 ml of PSB + 100% N and P), T_4 (Seed treatment with 160 ml of PSB + 100% N and P). The minimum net returns of Rs.27321 ha^{-1} is found under treatment T_1, because no application of organic and inorganic fertilizers. Similar finding were also found by Tomar *et al.*, 2017 [69] and Singh *et al.*, 2019 [75].

Benefit cost ratio (B:C Ratio)

The maximum benefit cost ratio of 2.64 was found under treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) and minimum benefit cost ratio of 1.93 found under treatment T_1 (Control Plot). Similar observations were also observed by Rachana *et al.*, 2018 [15], Singh S *et al.*, 2018 [79] and Suryavanshi *et al.*, 2017 [71].

Table 7: Effect of different biofertilizer applications on gross returns, net returns, benefit cost ratio of spring maize

Treatments	Gross Returns (Rs/ha)	Net Returns (Rs/ha)	B:C Ratio
T_1	56639	27321	1.93
T_2	85899	48166	2.27
T_3	87989	50657	2.36
T_4	112442	69382	2.61
T_5	99693	56093	2.54
T_6	119757	73675	2.59
T_7	128535	79981	2.64

Conclusion

The results obtain from research experiment showed that the maximum performance in growth parameters (plant height, number of leaves per plant, LAI) was observed in treatment T_4 (Seed treatment with 160 ml of PSB + 100% N and P. In terms of grain yield and yield parameters (number of cobs per plant, number of grains per cob, 1000-grain weight, cob length, cob girth, number of grain rows per cob) treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produces maximum grain yield and yield parameters. The available nutrients status in soil was also increases with the applications of biofertilizer. Therefore, it may be concluded that treatment T_7 (Soil application of 450 g *Azotobacter* + FYM + 100% N and P) produces the most during the *spring* season in Punjab's central plain.

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