Original Research Article

Effect of Inorganic Nutrients and Biofertilizers on Growth, Yield and Soil Properties ofMaize(*Zea mays* L.)in N-WRegion ofPunjab

Abstract

Thefieldexperimenton"Effectofinorganicnutrientsandbiofertilizersongrowth and yield of Maize (*Zea mays*. L) in N-W region of Punjab" was carried out at theresearch farm of Guru Kashi University,Talwandi Sabo, Bathinda (Punjab) during kharifseason 2022. The experiment comprising total 8 treatment combinations; *viz*:, T_0-control, T_1-(100 percent RDF), T_2NP(150 kg per ha;70 kg per ha), T_3-NP (100 kg per ha; 40 kg per ha)+ Azospirillum, T_4-NPK(140 kg per ha;70 kg per ha;70kg per ha),T_5-NPK (110 kg per ha;40 kg per ha; 30kg per ha)+Azotobacter,T_6-NPK+Zn(150kg per ha;70 kg per ha;70kg per ha)+50 kgper ha,T_7-NPK+S+S+Zn(160kg per ha;70kg per ha;70kg per ha)+50 kg per ha +30 kg per ha, T_8-NPK (110kg per ha; 50kg per ha; 50kg per ha) + Azotobacter +Azospirillum.Experiment was carriedout in randomized block design with three replications. Resultsrevealedthatgrowth,yieldandeconomicsofMaizeinfluencedsignificantlyduetoapplication of nitrogen practices. The highest grain yield of 59.70 quintal per haand stover yield 93.4quintal per ha wasrecordedwithcombinedapplicationofNPK+ S+Zn(160 kg per ha;70 kg perha;70 kg per ha)+ 50 kg per ha + 30 kg per ha (T_7).

Keywords:*Inorganic,Biofertilizers,Growth,YieldandMaize*

Introduction

Among the species of cultivated plants, maize (*Zea mays* L.) has been a fantasticsource of plant genetic material for both basic and applied genetic research. It is the mostproductive and produced cereal in the world. It holds a dominant position as a tradable goodin the global economy(Edmeades *et al*, 2017). There are several uses for it, but principally forfood, feed, and as a raw material for industry. In India, after rice and wheat, maize is the thirdmost popular food grain. But over the past ten years, maize production and productivity havegrown at a pace of 4.2 percent annually in our nation, the most among all food grains,including rice and wheat (Erenstein*et al*, 2022). One of the most significant cereal crops ismaize (*Zea mays* L*.),* which is ranked third globally and second in India among all cerealcrops. Because of its greater adaptability, it can be cultivated twice a year, once in the earlyand once in the late seasons. It also goes by the name "Queen of Cereals"(Behera *et al*, 2019).The controlof nutrientshasa significantimpacton the production of any crop, includingcorn. 72% carbohydrate, 10% protein, 3.5% fibre, and 1.7% ash are all present in maize (Gao*et al*,2020).

India produces 14.36 million tons of maize annually, covering 67.49 million acres,placing it fifth in the world in terms of area and seventh in terms of overall production(Poole*et al*, 2021).Indian conditions require increased output; hence attempts are being made todevelop high-yielding, fertilizer-responsive, and non-lodging cultivars(Erenstein*et al*, 2022).This led to the widespread usage of expensive inorganic nitrogenous fertilizers, which alsocontributetowaterandairpollution,intheprocessofreplenishingsoilnutrients.Only50%of the total nitrogenous fertilizers used are absorbed by the plants, with the remaining 50%being lost through leaching, denitrification and volatilization (Anas *et al*, 2020). Despite ourbest efforts to boost the production of fertilizers through industrialization, our nation has notbeen able to meet the need for fertilizers, and the supply-demand imbalance is widening. Inordertoacquirefertilizersfromindustrializednations,weareneededtomakesignificantforeignexchangeinvestmentsduetotherisingdemand(Dilshad*etal*,2010).Additionally,the government's strategy of cutting fertilizer subsidies has made things worse for farmers;therefore it is urgent that a technology aimed at reducing the consumption of pricey inorganicfertilizersbedeveloped (Edmeades*et al*, 2017).

A ground-breaking innovation in the field of research includes using hormones toinducenodulationongrainrootsandN-fixingmicroorganismstofacilitatenitrogenfixation.

Positive effects on the formation of nodule-like structures in cereals have been attributed tothe addition of the biofertilizer. Additionally, numerous crops have reported benefiting fromthe associative diazatroph*Azospirillum*(Bennett *et al*, 2020 and Rosenblueth*et al*, 2018). Byboosting root biomass, increasing its ability to fix nitrogen, or doing both, the bacteriumcontributestohigheryieldsofcrops,particularlygrains.Accordingtoreports,*Azospirillumbrasilenee*hasimprovednitrogenaseactivityaswellasotherphysiologicalprocesses,which has led to a highermaizeyield(Dent andCocking, 2017).

The majority of nitrogen fixers that are free-living are *Azotobacter*, *Beijerinckia*,*Azospirillum*, *Herbaspirillum*, *Gluconacetobacter*, *Burkholderia*, *Clostridium*, *Paenibacillusand Methanosarcina*which have demonstrated great efficacy in cereal crops (such as growthand grain yield of cereals) (Ladha *et al*, 2016; Ritika and Utpal, 2014).Additionally, theprevalence of Azotobacter species in the soil may increase the availability of P as well as Nthrough the BNF processes (Din *et al*, 2019). Furthermore, a 2009 study by Kizilkaya showedthat soil carbon and sulphur levels increased in response to inoculation with Azotobacterspeciesbyspeedingupthemineralizationofsoilorganicwastes,whichsubsequentlydecreased theabsorptionof heavymetals byroots.

In many nations, it has been heavily utilized as a production technology, resulting in a20–29 per cent increase in yield (Ryu *et al*, 2020). The sources of organic fertilizer maintainhealthy soil aeration by enhancing soil structure and give plants nourishing nourishmentwithout leaving behindany chemical residue.However, organic fertilizers are expensive,slow to release, and they lower crop yields in general. Manure is an organic fertilizer sourcethat, in contrast to chemical fertilizers, has a lasting impact on subsequent crops and reducesnutrient loss through evaporation, soil erosion, and leaching. Manure nutrients release toplants very gradually (Das and Das, 2004 & Singh *et al*, 2018). When compared to organicfertilizer sources, inorganic fertilizer sources are more affordable, release sooner, and requiremuch less. However, they harm the soil, pollute the air and water, and pose a major threat tohumanhealth.

Agro-ecosystem sustainability requires the combined use of organic and inorganicfertilizer sources (Rao *et al*, 2002). Higher grain production is obtained when recommendedfertilizer doses are combined with farmyard waste. It is advised to apply NPK 20:0:10: at 450kg per hectare and poultry manure at 30 tones per hectare to increase the grain production ofmaize.Useofcowdungandpoultrymanurecanacceleratethegrowthofmaize'sroots.

Vermicompostusedinconjunctionwithinorganicfertilizersourcescanincreasemaizequality and yield while also enhancing the soil's (physical, chemical, and biological) qualities.It can also satisfy the crop's nutrient needs during the entire growth cycle. The growth andyieldof maizewill beimproved bycombiningsourcesof organicand inorganicfertilizer.

The essential component for achieving a good crop production is phosphoric fertilizer.The developing and storing organs, like fruits and vegetables, are phosphorus-rich. By aidingin the translocation of carbohydrates, it encourages strong root growth and fruit ripening.There are also reports of a higher glucose concentration. It is a crucial component of theplasmamembrane,nucleicacids,manycoenzymes,andorganicmoleculesincludingATPand other phospho-related compounds. It is crucial for oxidation reduction processes andenergy transfer reactions. Within plants, phosphate molecules function as “Energy current."Photosynthesis and the metabolism of carbohydrates produce energy that is used for thedevelopmentandreproductionprocesses.Consequently,phosphorusisacrucialcomponenttoimproveoutput(Ryu *et al*, 2020).

Objectives:

1. To study the effects of inorganic nutrients and bio fertilizers on growth and yield of Maize.
2. To study the effects of inorganic nutrients and bio fertilizers on Pysico-chemical properties of soil.
3. To study the effects of inorganic nutrients and bio fertilizers on economics of Maize Crop.

MATERIALSANDMETHODS

Experimentalsite and Experimental details

Geographically theexperimentalsite of research farm ofGuru KashiUniversity,Talwandi Sabo, (Bathinda) during *Kharif* 2021. The farm is located at 29°57'N latitude and75°07'E longitude at anelevation of about 213meters above mean sea levelin North-Westernregion of Punjab.Thistractischaracterizedbysemihumidclimatewherebothwintersandsummersare extreme. A maximum temperature about 45^0- 48^0 is not uncommon in during summer.While freezing temperature accompanied by frost occurrence may be witnessed of Decemberand January. The monsoon generally starts in first week of July.The accurate weather reportofTalwandi Sabo (Bathinda)from September to March isgiven below.

T_{0-}(Control), T_1 -(100%RDF),T_2 -NP (150kg/ha;70kg/ha), T_{3-}NP (100kg/ha; 40kg/ha) +*Azospirillum*, T_{4-}NPK(140kg/ha;70kg/ha;70kg/ha), T_{5-}NPK(110kg/ha;40kg/ha;30kg/ha)+*Azotobacter*, T_{6-}NPK+ Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha, T_{7-}NPK+ S+ Zn (160kg/ha; 70kg/ha; 70kg/ha) +50kg/ha+30kg/haT_{8-}NPK (110kg/ha; 50kg/ha; 50kg/ha) +*Azotobacter*+*Azospirillum.* Variety-PMH-2 was used as experimental material for sowing purpose ata depth of 3-5 cm using a spacing of 60 cm × 15 cm using 25 kg/ha recommended dose ofsowingseed. Kharif season crop under year 2021-23, Numberoftreatments-8, No.ofreplications-3, Totalnumber ofplots-24, Grossplotsize-4.5m x4.5m, Experimentaldesign-Randomizedblock design.

RESULTSAND DISCUSSION

Growthparameters of*Maize*

Plantheight

The data pertaining to plant height of Maize at different stages of crop growth (30 DAS and at harvest) are presented in table 1. The results revealed that the plant height of maize increased progressively increase with increase in the age of the crop. Both methods of planting and integrated nutrient management practices had a significant impact on plant height of maize. Plant height of maize as effected by different inorganic nutrients and after applying biofertilizers is given in table 1. At 30 DAS the plant height increased significantly from 35.34 cm (control) to 37.34 cm when recommended dosage of fertilizers was applied. Similarly the plant height further increased significantly to 36.34 cm in the presence of nitrogen (150 kg per ha and 70 kg per ha). In addition, the plant height has been further increased 38.34 cm in the presence of *Azotobacter*. In contrast the plant height has been decreased to 35.34 cm when zinc was applied at 50kg per ha and finally increased upto 36.34 cm when nitrogen, phosphorus and potassium (110kg per ha, 50kg per ha and 50kg per ha) in combination of *Azotobacter*&*Azospirillum*was supplied. The similar trend in plant height has been observed at 60 DAS and at the time of harvest (90 DAS). At harvesting the plant height increased significantly from 138.73 cm (control) to 140.12 cm in the presence of recommended dosage of fertilizers. Moreover it has further been increased up to 141.45 cm when nitrogen and phosphorus was applied at 150 kg per ha; 70 kg per ha). Similarly it has been further increased significantly to 142.87 cm when nitrogen, phosphorus and potassium (110 kg per ha, 50 kg per haand 50 kg per ha) in combination with *Azotobacter* + *Azospirillum* was applied.

Table 1. Effect of inorganic nutrients and bio-fertilizers on growth parameters at various growing stage of maize crop

	30 DAS	60 DAS	AT HARVEST (90 DAS)
Treatments	**Plant height (cm)**	**Plant height (cm)**	**Plant height (cm)**
T_0 (Control)	35.34	95.12	138.73
T_1 (100% RDF)	37.31	98.12	140.12
T_2 NP (150kg/ha; 70kg/ha)	36.33	97.12	141.45
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	35.34	97.45	138.76
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	38.32	97.76	141.98
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	39.31	98.12	139.90
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	35.25	98.78	142.95
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	35.34	98.99	142.99
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	34.34	99.57	`142.87
CD @ 5%	1.05	3.21	7.82
S.E m (±)	2.18	4.15	6.18

Table 2. Effect of inorganic nutrients and bio-fertilizers on growth parameters atVarious growing stage of maize crop

	30 DAS	60 DAS	AT HARVEST (90 DAS)
Treatments	**Leaf area index**	**Leaf area index**	**Leaf area index (cm^2)**

	(cm^2)	**(cm^2)**	
T_0 (Control)	1.05	2.05	2.05
T_1 (100% RDF)	1.90	2.72	3.29
T_2 NP (150kg/ha; 70kg/ha)	1.67	2.62	3.23
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	1.83	2.83	3.42
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	1.79	3.13	3.70
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	1.86	2.79	3.53
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	1.92	2.78	3.42
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	1.95	3.29	3.63
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	1.98	3.93	3.94
CD @ 5%	0.14	0.28	0.32
S.E m (±)	0.09	0.10	0.11

Table 3.Effect of inorganic nutrients and bio-fertilizers on growth parameters at various growing stage of maize crop

	30 DAS	**60 DAS**	**AT HARVEST (90 DAS)**
Treatments	**Dry matter accumulation (g/plant)**	**Dry matter accumulation (g/plant)**	**Dry matter accumulation (g/plant)**
T_0 (Control)	10.75	24.60	38.27
T_1 (100% RDF)	17.87	43.01	76.04
T_2 NP (150kg/ha; 70kg/ha)	14.42	42.00	75.65

T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	21.89	43.10	77.89
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	20.46	41.89	76.98
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	19.43	42.00	84.89
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	19.57	44.56	88.06
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	20.83	49.79	92.98
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	22.33	51.53	101.13
CD @ 5%	1.85	4.45	8.55
S.E m (±)	0.64	1.55	3.04

Mean followed by same letter(s) within a column are not significantly different at 5 percent level of significance using Duncan Multiple Range Test (DMRT), DAS= Days after Sowing; RDF recommended dose of fertilizer (NPK); T0 (Control); T_1 (100% RDF); T_2 NP (150kg/ha; 70kg/ha); T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*; T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha); T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) +*Azotobacter*; T_6NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha; T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha; T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter* + *Azospirillum.*

The application of nitrogen fertilizer level with increasing levels has significantly increased the plant height due to the positive effect of nitrogen element on plant growth. Similar finding was reported by Asif *et al*, (2013) where there is significant effect of N and Zn observed in maize which attributed to more vegetative development that resulted in increased mutual shading and intermodal extension. Nitrogen is vital as it is the main component of chlorophyll, amino acids and building blocks of protein. Providing adequate nitrogen allows the crop to grow to full maturity rather than delaying it. Increase in plant height in response to higher N levels has also been confirmed by Akbar *et al*, (2002) and Rasheed *et al*, (2004). According to the findings of De Lucca *et al*, (2012) inoculation treatments of maize seeds with liquid

Azospirillumbrasilense also cause an increase in the height of plants. According Puente *et al*, (2009), the inoculation with the optimal bacterial concentration of *Azospirillum* increased plant height.

Leaf area index

Leaf area (LA) explains how efficiently the nutrients were used for metabolic activities by growing crop in the field. Leaf area (LA) explains how efficiently the nutrients were used for metabolic activities by growing crop in the field. Leaf area index of maize as affected by different level of nitrogen, phosphorus, potassium, zinc, sulphur and biofertilizers (*Azotobacter + Azospirillum)* is presented in Table 2 It is evident from the table that the increasing level of nitrogen have influenced leaf area index significantly from (control) to when nitrogen fertilizer was applied at 30 DAS, similarly the leaf area index further increased to. The results showed that leaf area index and harvest index increased with increasing levels of fertilizers. The leaf area index in the control was 1.19 which increased to 1.87 with 50 per cent of the recommended NPK dose and to 2.57 with recommended NPK dose. The leaf area index further increased when mineral fertilizers were applied in combination with organic sources. Thus, with recommended NPK and 10 Mg ha^{-1} FYM treatment (RNPK + FYM10), the leaf area index was 3.23 and with 50% of the recommended NPK plus 20 Mg FYM and 1.5 kg ha^{-1} Azotobacter inoculum (RNPK50 + FYM20 + AI1.5), leaf area index was 3.26 which was the highest amongst all treatments. This may be attributed to the role of N in vegetative growth of the plants and its influence on utilization of P, K and other nutrient elements (Inamulhaq and Jakhro, 1996)**.** Furthermore, FYM ensure slow release of N through its mineralization and N-fixation through Azotobacter ensured N supply to plants throughout their life cycle causing more vegetative growth (Ali and Bhatti, 2008).

Dry matter accumulation

In the similar manner, maximum dry weight at 60 DAS was received in treatment T6 (23.10 g) and it was found that T12 (23.00 g) was found to be significant and is statistically at par with treatment T6. The results were similar with the findings by Cohen *et al*, (1980) which showed that inoculation of plants with *Azospirillum* showed significant increase of root and dry shoot dry weight reported in Maize. Carletti, (2000) reported that *Azotobacter* fixes air nitrogen and produces plant growth promoters with increase in plant growth and the number of hair roots and plants take up more water and nutrients. *Azotobacter* fixes air nitrogen and produces plant growth promoters with increase in plant growth and the number of hair roots and plants take up more water and nutrients. These results were similar with findings by Carletti, (2000). The results were also similar with findings by Cohen *et al*, (1980) who reported that *Azospirillum*inoculated plants showed significant increases of root and shoot dry weight of plants in maize. De Lucca *et al*, (2012) found that inoculation of maize seeds with *Azospirillumbrasilense*also causes a significant increase in the plants' dry matter. According to Puente *et al*, (2009), the inoculation with the optimal bacterial concentration of *Azospirillum* increased root length and root and aerial dry weight.

Yield attributes of Maize

Final Plant Population

Number of grains per cob

It is evident from the data presented in the Table 4 that grain rows cob^{-1} (cm) was affected significantly by combination of biofertilizers, nitrogen and zinc. The highest grain row (14 cm) was recorded with the inoculation of Azospirillum + 150 kg ha^{-1} N + 15 kg ha^{-1} Zn (T_6) and remained at par to T_2, T_3, T_4, T_5, T_6,T_7, T_8, but significantly superior to T_1. The number of grain rows per cob varied with nutrient application as these outcomes substantiate by the findings of Bakry *et al*, (2009) who reported that different micronutrients and their combination was testified on maize crop which proved beneficial and salubrious in enhancing all physiological and yield parameters of maize crop and also gave a good response in terms of number of grain. On the basis of experiment conducted by Kruczek, (2005) by applying different levels of multi-component fertilizers gave a significant effect on number of grain rows per cob.

Number of cobs per plant

Length of cob

Cob height is the internodal point where the cob for development of cob is established.

Diameter of cob

The results on cob diameter (cm) as affected by nitrogen management techniques using biofertilizers and zinc are shown in Table 4, and it was discovered that the cob diameter was not significant compared to the other treatments. The inoculation of Azospirillum + 150 kg ha^{-1} N + 15 kg ha^{-1} Zn (T_6) produced the cob diameter with the greatest value (13.09 cm), and the cob diameter with the lowest value (11.65 cm) was obtained with Azospirillum + 90 kg ha^{-1} N + 15 kg ha^{-1} Zn (T_4). According to some experts' findings, applying nitrogen fertiliser increased the cob diameter values (Kara *et al*, 1999; Turk and Alagoz, 2018).

Table 4. Effect of inorganic nutrients and biofertilizers on growth components of maize crop at harvest`

Treatments	Final Plant population (no)	Length of cob (cm)	Diameter of cob (cm)	Number of cobs/ Plant	Number of grains/ cob
T_0 (Control)	130	9.03	8	1.1	280.33
T_1(100% RDF)	168	13.75	14	1.2	390.47
T_2 NP (150kg/ha; 70kg/ha)	168	15.06	15	1.2	398.20
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	168	13.09	13	1..2	376.23
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	170	14.60	15	1.2	362.10
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	171	14.44	15	1.1	363.17
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	169	11.03	15	1.3	387.17
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	171	15.96	16	1.2	404.37
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	173	16.82	16	1.3	424.83
S.Em ($\pm$)				2.25	2.41
CD at 5 %				6.74	7.28

Table 5. Effect of inorganic nutrients and biofertilizers on growth components of maize crop at harvest

Treatments	Grain yield/cob (g)	100-grain weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	Harvest index (%)
T_0 (Control)	75.20	15.33	25.33	35.3	36.55
T_1(100% RDF)	89.70	23.41	42.20	72.3	36.86
T_2 NP (150kg/ha; 70kg/ha)	103.4	26.57	37.30	68.1	35.39
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	75.20	20.36	39.40	61.4	39.09
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	86.88	24.90	48.20	79.6	37.72
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	87.12	24.09	45.20	83.6	35.09
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	88.32	23.05	50.10	86.4	36.70
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	101.00	25.01	59.70	93.4	38.99
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	97.52	23.80	52.00	89.7	36.70
S.Em (±)			2.25	2.41	
CD at 5 %			6.74	7.28	

Table 6:- Economics and incremental cost benefit ratio of different inorganic nutrients and bio-fertilizers

Treatments	**Mean Seed yield (q/ha)**	**Increase yield over control (q/ha)**	**Return increased yield (Rs. /ha)**	**Total cost (Rs./ha)**	**Net profit (Rs./ha)**	**Incremental cost benefit ratio**
T_0 (Control)	30.20	0.0	-	-	-	-
T_1(100% RDF)	42.20	12.0	23400	5432	17968	3.31
T_2 NP (150kg/ha; 70kg/ha)	37.30	7.1	13845	5353	8492	1.59
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	39.40	9.2	17940	4152	13788	3.32
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	48.20	18.0	35100	6637	28463	4.29
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	45.20	15.0	29250	4867	24383	5.01
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	50.10	19.9	38805	7475	31330	4.19
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	59.70	29.5	57525	7918	49607	6.27
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	52.00	21.8	42510	5892	36618	6.21

4.3.6 Grain yield per cob

Application of nitrogen in combination with biofertilizers and zinc has increased the number of grains per cob insignificantly in this field experiment. The increment in number of grains per cob might be due to the presence of magnesium in multi-nutrients solution as grains number are direct index of pollen viability and where magnesium is proved to increase fruit set and pollen viability and significant effect on pollen formation as reported by Saracoglu *et al*, 2011.

4.3.7 100-grain weight

Regardless of the type of fertiliser (bio- and/or chemical fertilisers), the most effective method of application of ear length, number of rows/ear, number of seeds/row, 100 grain, weight, and grains yield/plant is with dressing soil application because microorganisms have the ability to produce some growth regulator substances, by root colonising bacteria, which it may play a significant role in plant growth by promoting photosynthesis, translocation, and accumulating (Panwar *et al*, 2006; Tarang *et al*, 2013).

4.3.8 Grain yield

Results presented in Table 4 indicated that the highest grain yield of 59.70 q/ha was recorded with combined application of NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha (T_7) andsignificantly superior to rest of the other treatments. This was followed by treatment of NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*andNPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha and both the treatments were statistically at par to each other. The lowest yield (37.30 q/ha) was recorded in the treatment of NP (150kg/ha; 70kg/ha) (T_2) and NP (100kg/ha; 40kg/ha) + *Azospirillum*and these treatment were statistically at par to each other. Rest of the treatments were found in middle order in yield potential.The present findings are similar to Singh *et al*, (2018) they found that the highest yield was recorded by the application of recommended NPK with micronutrients to compare alone application of recommended NPK. The present findings are similar to Mahata*et al*, (2023) he observed that the growth and yield parameters of hybrid maize varieties increased significantly with increasing nitrogen levels. These results are also supported by Gaj*et al*, (2013) they found that the a positive significant relationship was shown between the nutritional status of maize and grain yield. Inoculation with Azospirillum resulted in significant yield increases of the magnitude 10 to 30 percent (Bashan *et al*, 2004)Similar findings by Hajnal-Jafari*et al*, (2012) who indicated that grain yield increased with inoculation by Azotobacter. The findings were also similar to Sepat and Kumar, 2007who observed that Azotobacterchrococcum significantly increased grain yield of maize over no inoculation. The yield of grains significantly increased when Azospirillumbrasiliense or commercial bio-fertilizers were used in conjunction with a half-dose of N (144kgN/ha). Additionally, the crop's seed production was increased by seed inoculation with Rhizobium, phosphorus-solubilizing bacteria, and organic amendment (Panwar *et al*, 2006).

4.3.9 Stover yield

Similar to grain yield, the highest stover yield 93.4 q/ha was observed in the treatments ofNPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha (T_7) followed by treatment of NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*andNPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha and these treatments were statistically at par to each other. The lowest stover yield 61.4 q/hawas recorded in the treatment of NP (100kg/ha; 40kg/ha) + *Azospirillum*followed by NP (150kg/ha; 70kg/ha). Rest of the treatments werefound middle order in stover yield potential. The present findings are supported by Singh *et al*, (2018) observed that the highest stover yield was recorded by the application of recommended NPK with micronutrients. These results were also similar to Mahata*et al*, (2023) found that the stover yield in increase with the increase of nitrogen level.

4.3.10 Harvest index

Data presented in Table 5 indicated that the highest (39.09) harvest index was recorded in the treatment of NP (100kg/ha; 40kg/ha) + *Azospirillum*(T_3) followed by treatment of NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha and NPK (140kg/ha; 70kg/ha; 70kg/ha). The lowest harvest index (35.09) was recorded in the treatment of NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*followed by NP (150kg/ha; 70kg/ha). Yazdani *et al*, (2009) showed that application of bio-fertilizers in combination with fertilizer (NPK) graduallyimproved ear weight, row number, biological yield and harvest index and grain number/row andultimately increased grain yield of maize.

4.3.11 Net profit and Incremental cost benefit ratio

Datapresented in Table 5 indicated that the maximum net profit (Rs. 49607) and highest incremental cost benefit ratio (6.27) was recorded in the treatment of NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha (T_7) followed by NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum.* The lowest net profit and B C ratio was recorded in the treatment of NP (150kg/ha; 70kg/ha) followed by NP (100kg/ha; 40kg/ha) + *Azospirillum.* These results were supported by Singh *et al*, (2018) observed that the highest B C ratio and net profit was recorded by the application of NPK with micronutrients.

4 Analysis of physiochemical properties of soil

4.4.1 Physical and chemical properties of soil

Table 6 presents the data on Analysis of physiochemical properties of soil after maize harvest compared with control, all the treatments significantly increased soil pH, EC, Available N, P, K, S, Bulk density, particle density and porosity. Organic fertilizer applied at 10 t/ha had the highest soil pH (6.23), OM (2%) and N (0.14%). Organo-mineral fertilizer applied at 10 t/ ha recorded the highest soil available P (10.05 mg/kg) and K (0.51 C mol /kg). application of 300kg/ha NPK15:15:15 fertilizer reduced soil pH while OG and OMF increased soil pH the increase in soil pH and OM by OG and OMF might be related to the high amount of N and P in the fertilize formulation. This finding corroborates with the work of Okunlola *et al*, (2011) who found that organic manures increase soil pH and OM, N, P, K, Ca and Mg.

4.4.1.1 Bulk density, Particle density, Porosity, Chemical properties, EC and pH

Results showed that the physical and chemical parameters of soil were significantly affected by the application of biofertilizersand inorganic fertilizers.

Soil pH value of 7.9 was recorded in control (a little alkaline) whilst; minimum pH value (7.25) was recorded in T_4 followed by $T_2$where inorganic nutrients were applied both alone or in combination. Hence, addition of biofertilizersirrespective to its nature, elevatedthe soil pH. Significant differences among the treatments were observed in soil bulk density, particle density and porosity as compared to the control.Combination of organic manures might have improved the nitrogen use efficiency, micro and macro nutrient recovery and help in P solubilization and its uptake by the plants and enhanced K availability that in turn resulted in better growth and yield of maize. Increased organic matter due to application of organic manures improved crop performance and soil characteristics (Lima *et al*, 2009). Therefore, combined application of organic and inorganic fertilizers is considered a good

Table 7. Physical and chemical characteristics of the soil among different fertilizer treatments after the harvest of maize (Same letter within each column indicate no significant differences among the treatments (P ≤ 0.05)

Treatments	**pH (1:2)**	**EC (dSm^{-1})**	**Available N (kg/ha)**	**Available P (kg/ha)**	**Available K (kg/ha)**
T_0 (Control)	7.90	0.21	256.1	4.7	126.6
T_1(100% RDF)	7.56	0.22	254.5	4.67	126.4
T_2 NP (150kg/ha; 70kg/ha)	7.29	0.19	308.4	136.8	107.9
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	7.30	0.18	312.5	138.5	122.5
T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	7.25	0.20	318.8	140.0	144.8
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	7.37	0.20	334.5	166.1	208.7
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	7.38	0.21	341.2	223.1	245.5
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	7.39	0.20	345.4b	224.8	252.5
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	7.40	0.20	352.5b	225.4	265.6
CD (p=0.05)	0.161	0.458	22.60	10.75	15.55

Table 8. Physical and chemical characteristics of the soil among different fertilizer treatments after the harvest of maize

Treatments	**Available S (kg/ha)**	**Bulk density ($Mg\ m^{-3}$)**	**Particle density ($Mg\ m^{-3}$)**	**Porosity (%)**
T_0 (Control)	11.6	1.59	2.56	37.89
T_1(100% RDF)	10.6	1.58	2. 54	37.79
T_2 NP (150kg/ha; 70kg/ha)	20.0	1.53	2.56	40.23
T_3 NP (100kg/ha; 40kg/ha) + *Azospirillum*	21.6	1.54	2.56	39.85

T_4 NPK (140kg/ha; 70kg/ha; 70kg/ha)	22.8	1.55	2.54	38.97
T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*	26.0	1.49	2.56	41.80
T_6 NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha	34.3	1.56	2.53	38.34
T_7 NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha	35.8	1.56	2.57	39.30
T_8 NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*	37.5	1.57	2.54	38.19
CD (p=0.05)	1.58	0.012	_____	_____

option to enhance nutrient recovery, plant growth and ultimate yield otherwise higher N and P application rates are required to attain better yield in maize (Khuram *et al*, 2013).

Addition of organic manures, regardless to its nature, abridged soil pH. Similar findings were also reported by Yaduvanshi, (2003) that a reduction of soil pH occurs when green manure or farmyard manure was used in alkaline soils. Low pH value for FYM is very valuable for calcareous soils (Karami *et al*, 2012). Further, reduced bulk density might be due to increased soil biopores and soil aeration, higher soil organic carbon content, and better soil aggregation by the application of bulky organic manures that ultimately improved soil porosity and water holding capacity as well (Gangwar *et al*, 2006). Organic manure (from different sources) application enhanced soil porosity, soil moisture contents and water holding capacity while reduced soil compaction and bulk density (Papini *et al*, 2011). Moreover, Bandyopadhyay *et al*, (2010) also reported a negative correlation of soil bulk density of top 15 cm soil layer with the organic carbon contents present in it.

Available NPK

The application of biofertilizers increased soil P available and nitrogen.This demonstrated that applying biofertilizers containing bacteria that fix nitrogen and solubilize phosphorus (P) improved the soil's N content and P availability. These outcomes are consistent with the studies. According to Li *et al*, 2010 inoculation of P-solubility and N-fixing microbes increased soil availability of P, nitrogenize activity, and plant biomass. It was also possible to expand the PSB population in the soil through the injection of P solubilizing bacteria, which increased P solubility. The expansion of P-solubilizing microbes and P solubilizationwere positively correlated with the studies conducted by Nosrati *et al*, (2014). Plant–microbe interactions in the rhizosphere are the main factor for plant growth and soil fertility. The current study indicated that the plant growth, yield and grains quality of maize were positively affected by the application of biogas slurry, humic acid, biofertilizers, and their combinations. The effective role of biofertilizer inoculation on plant growth could be related to its ability to produce high quantities of auxin, such as indole acetic acid. Moreover, these microorganisms and AMF have the potential for N fixation, and P and K mobilization, leading to enhanced nutrient uptake and plant growth (Abdel-Fattah *et al*, 2014). Previous studies also reported that the N-fixing and P-solubilizing bacterial strains had the ability to provide nutrients and stimulate each other through their physical and biochemical activities and, subsequently, enhancing the physiological properties of plants (Jha and Saraf, 2012). A similar study has also shown that application biofertilizers, humic acid, and their combinations positively affected plant growth parameters (Abou-Aly and Mady, 2009).

Fig 1. Study investigation and field work

SUMMERY AND CONCLUSION

An investigation was conducted to study the "**Effect of Inorganic Nutrients and Biofertilizers on Growth and Yield of Maize (*Zea mays* L.) in N-WRegion of Punjab**" at the experimental farm, Guru Kashi University, Talwandisabo (Bathinda) during rabi season 2022-23.The experiment comprised of eight treatments T_0 (Control); T_1(100% RDF); T_2 NP (150kg/ha; 70kg/ha); T_3NP (100kg/ha; 40kg/ha) + *Azospirillum*; T_4NPK (140kg/ha; 70kg/ha; 70kg/ha); T_5 NPK (110kg/ha; 40kg/ha; 30kg/ha) + *Azotobacter*; T_6NPK + Zn (150kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha; T_6NPK + S + Zn (160kg/ha; 70kg/ha; 70kg/ha) + 50kg/ha + 30kg/ha; T_7NPK (110kg/ha; 50kg/ha; 50kg/ha) + *Azotobacter*+ *Azospirillum*. The experiment was laid out in split plot design and replicated thrice.

The findings of the study project demonstrated that addition of bio-fertilizers with good management is not required but does allow for better timing during plant growth. Due to the ideal values of physical and chemical properties, the highest values of the investigated soil fertility parameters were found during the time of the study year with better precipitation distribution during the vegetation period. The interaction between fertilizer application and sampling period revealed that the impact of applied fertilizers on the two cultures tested for their effect on the growth parameters, development stages, and yield parameters of maize crop.

Over the course of a one year study, analysis of grain yield and the chemical makeup of both tested cultures, including nitrogen, phosphorus, potassium, and sulphur, showed significant differences between these parameters and the applied fertilization treatments. The best results were obtained in the treatment, which included a combination of high amounts of mineral NPK fertilizers and microbial inoculants. It was also found that the combined application of microbial inoculants and lower doses of mineral NPK fertilizers increased the yield of maize and compared to the use of only NPK fertilizers in our case study. Furthermore, the combined treatments had better results than the individual ones with big variations, particularly the ones linked to the applied organic manure. The beneficial impacts of the studied treatments are therefore more likely to have improved the availability of micronutrients in the soil and their ability to accumulate in the maize grain, which closely correlated with their equivalent available contents in the treated soil plots.

References:

Anas, M., Liao, F., Verma, K.K., Sarwar, M.A., Mahmood, A., Chen, Z.-L., Li, Q., Zeng, X.-P.,Liu,Y.,Li,Y.-R.,(2020).Fateofnitrogeninagricultureandenvironment:agronomic,eco-physiologicalandmolecularapproachestoimprovenitrogenuseefficiency.*Biol. Res*. *53*,1–20.
Nigel Poole, Jason Donovan and Olaf Erenstein. 2021. Viewpoint: Agri-nutrition research: Revisiting the contribution of maize and wheat to human

Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K., Prasanna, B.M., 2022. Global maizeproduction,consumption andtrade: trendsand R&Dimplications. FoodSecur.1–25.
nutrition and health. *Food Policy*. 101976. https://www.sciencedirect.com/science/article/pii/S0306919220301809?via%3Dihub

Edmeades,G.O., Trevisan,W., Prasanna,B.M., Campos, H.,2017. Tropicalmaize(*Zea mays* L.),in:Genetic ImprovementofTropicalCrops. Springer,pp.57–109.

Dilshad, M.D., Lone, M.I., Jilani, G., Malik, M.A., Yousaf, M., Khalid, R., Shamim, F.,2010.Integrated plant nutrient management (IPNM) on maize under rainfed condition.Pak. J. Nutr9, 896–901.

Karami, A., Homaee, M., Afzalinia, S., Ruhipour, H., Basirat, S., 2012. Organic resourcemanagement:Impactsonsoilaggregatestabilityandothersoilphysico-chemicalproperties.Agric. Ecosyst. Environ. 148, 22–28.

Gangwar, K.S., Singh, K.K., Sharma, S.K., Tomar, O.K., 2006. Alternative tillage and cropresidue management in wheat after rice in sandy loam soils of Indo-Gangetic plains. SoilTillageRes. 88, 242–252.

Gao, C., El-Sawah, A.M., Ali, D.F.I., AlhajHamoud, Y., Shaghaleh, H., Sheteiwy, M.S.,2020. The integration of bio and organic fertilizers improve plant growth, grain yield,qualityand metabolism of hybrid maize(*Zea mays*L.).Agronomy10,319.

Behera, B., Das, T.K., Ghosh, S., Parsad, R., Rathi, N., (2019). Effects of brown manurespecies,seedrateandtimeofapplicationof2,4-Donweedcontrolefficiency,productivityand profitabilityin maize.*IndianJournal ofWeedScience*. *51(4)*393-397.

Abdel-Fattah, G.M., Asrar, A.A., Al-Amri, S.M., Abdel-Salam, E.M., (2014). Influence ofarbuscularmycorrhiza and phosphorus fertilization on the gas exchange, growth andphosphataseactivityof soybean(*Glycine max*L.) plants.*Photosynthetica*52,581–588.

Abou-Aly, H.E., Mady, M.A., (2009). Complemented effect of humic acid and biofertilizersonwheat(*Triticumaestivum*L.)productivity.*Ann. Agric.Sci.*,*Moshtohor 47*, 1–12.