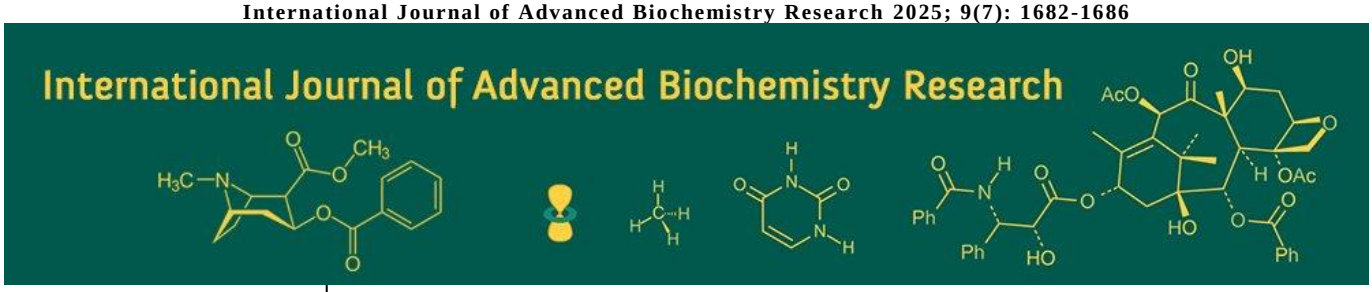

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Effect of graded levels of NPK fertilizers and microbial consortia on yield and yield attributes of maize in vertisol

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Abstract
The field experiment was conducted during *Kharif* season of 2024-25 at Wheat and Maize Research Unit of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The study involved eight treatment combinations, including different graded levels of NPK and microbial consortia (comprising *Azotobacter*, *Bacillus megaterium*, and *Frateuria aurantia*), namely: control, microbial consortia alone, 50% NPK alone, 75% NPK alone, 100% NPK alone, 50% NPK + microbial consortia, 75% NPK + microbial consortia, and 100% NPK + microbial consortia. Treatments were arranged in a Randomized Block Design (RBD) with three replications. Seeds were treated with microbial consortia @ 200 ml per 10 kg of seed and applied at sowing along with the respective fertilizer doses. The findings revealed that plant height (tasselling-189.60 cm and harvest-195.67 cm), chlorophyll content (30 DAS-53.89 and 60 DAS-45.92), cob length (without husk) *i.e.* 21.17 cm and cob girth (without husk) *i.e.* 17.27 cm were significantly improved by the integrated use of 100% NPK + microbial consortia. The highest grain (3794.98 kg ha^{-1}) and straw yield (4680.20 kg ha^{-1}) were observed with the application of 100% NPK + microbial consortia.

Keywords: Integrated nutrient management, NPK levels, microbial consortia, maize yield, randomized block design

Introduction
Maize (*Zea mays* L.) which is a member of tribe Maydeae in the family Poaceae, is considered among the most significant cereals throughout the world. Maize, which is of Central American origin, has developed to be a staple food crop and has been termed as the queen of cereals because of the high genetic yield potential compared to those of other cereals. Maize is mainly cultivated in *Kharif* season and close to a sizeable portion of the cultivated land is covered by maize crops during this peak season. Maize mostly consists of carbohydrates (mostly starch consisting of amylose and amylopectin) which make up about 70-87%, 6-13% protein, 4 percent fat and about 2-6 percent oil. It is a raw ingredient to a wide range of food and industrial items that include starch, sweeteners, cooking oil, beverages, adhesives, industrial alcohol, and bioethanol. Maize is increasingly being grown all over and the top producers are the United States, China and Brazil. According to the report provided by FAOSTAT (2020) [4], the number of countries producing maize in total is more than 170, and the volumes sum around 1,147.7 million metric tons each year, with agricultural land of approximately 193.7 million of hectares under cultivation and the average production in the countries is 5.75 tons per hectare. The current farming techniques highly rely on inorganic fertilizers and insecticides. However, long-term and extreme consumption of such inputs by producers led to soil quality degradation and the onset of pest and pathogen populations with increased resistance to the traditional interventions (Kumar *et al*., 2010; Cai *et al*., 2016) [3, 7]. Berating of the agricultural inputs or their extra use can also harm the soil structure and cause the impediment of microbial activities. Specifically, to shoot the improvement of both the efficiencies of nutrients and the soil condition, it is important to conduct balanced fertilization measures.

The usage of microorganisms in agriculture is one of such sustainable options underlying the adherence to environmentally friendly approach to farming. Use of organic fertilizers may be used to introduce desirable microbes that auger development in the plant and give greater crop yields. The microbial agents are frequently used in the form of consortia, i.e. mixtures of several microbial strains, and not as single isolates. This shift toward consortia arises from the inconsistent field performance of individual strains, prompting increased interest in synergistic microbial communities.

Materials and Methods

The investigation was carried out at Wheat and Maize Research Unit, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS), aimed to evaluate the effect of graded levels of NPK fertilizers and microbial consortia on plant height, chlorophyll content, cob length (without husk), cob girth (without husk), grain and straw yield of maize in Vertisol. Maize was used as test crop. The experiment was laid out in randomized block design (RBD) with eight treatments and three replications. The study involved eight treatment combinations, viz. T_1 (Absolute control), T_2 (Microbial consortia), T_3 (50% NPK), T_4 (75% NPK), T_5 (100% NPK), T_6 (50% NPK + microbial consortia), T_7 (75% NPK + microbial consortia), and T_8 (100% NPK + microbial consortia). The fertilizers were applied @ 120:80:60 kg ha^{-1} (N: P_2O_5:K_2O) respectively. Seeds were treated with microbial consortia (*Azotobacter*, *Bacillus megaterium* and *Frateuria aurantia*) @ 200ml per 10kg of seeds. The analysis was conducted using established protocols. Statistical evaluation and interpretation of the data were performed in accordance with the techniques outlined in "Statistical Methods for Agricultural Workers" by Panse and Sukhatme (1985) [18].

Results and Discussion

Plant height

Seed inoculation of microbial consortia in combination with the application of the varied levels of NPK fertilizers had a significant effect on maize plant height at tasselling and harvest stages (Table 1, Figure 1). The tallest plants were recorded at tasselling stage in treatment T_8 (100% NPK + microbial consortia) with the height of 189.60 cm. This was statistically similar to T_5 (100% NPK) that also elicited significant growth in plants. Comparatively, the minimum plants were registered in the course of treatment T_1 (absolute control). During the harvest stage, the largest plant height of 195.67 cm was also registered under T_8 and the lowest plant height of 150.53 cm was registered in the control (T_1). Plants treated with T_5 (100% NPK) were 189.33 cm in height, statistically equivalent to T_8 and had significantly higher heights compared to control. Such findings indicate that the application of a combination of the recommended levels of NPK and microbial inoculants continue to increase plant height throughout the growth. The reason is most probably because nutrients were available in large quantities. Such results are in line with those studies provided by Subhashini (2016), Ranadev *et al*. (2019), Mtaita *et al*. (2019), and Ronya *et al*. (2020) [10, 13, 15, 17].

Chlorophyll content

Analysis of results recorded in the form of Table 2 shows that a combination of NPK fertilizer and microbial consortia had great impact on increasing chlorophyll levels both at 30 and 60 days after sowing (DAS). Treatment T_8 (100% NPK + microbial consortia) recorded the highest concentration (53.89) of chlorophyll at 30 DAS followed by T_7 (75% NPK + microbial consortia, 51.95) and T_5 (100% NPK, 53.18). Otherwise, the lowest (37.15) was observed in T_1 (absolute control). The same pattern was recorded at 60 DAS where the highest chlorophyll level (45.92) was experienced in T_8, whereas the lowest was (30.87) which was in T_1. T_7 (42.72), T_5 (43.11) and T_3 (42.34) exhibited significant similar groups of chlorophyll concentrations with T_8. These findings indicate that microbial consortia application in concert with recommended NPK applications raised the level of chlorophyll at important crops during a developmental period by considerable measure. This increase is explained by uptake of more nutrients and improved physiological performance. The results are consistent with the ones by Meena *et al*. (2024) and Rueda *et al*. (2016) [9, 16].

Cob length and girth (without husk)

The results presented in Table 3 also indicated that, seed inoculation with microbial consortia together with NPK fertilizers had significant effect on cob length and girth (without husk) at harvest compared to the control. Randomly, cobs were taken in each plot and their average length was observed. Longest cob of 21.17 cm in treatment T_8 (100% NPK + microbial consortia) was applied was also found to be similar to other treatments T_5 (100% NPK, 20.97 cm) and T_7 (75% NPK + microbial consortia) 20.37 cm). On the contrary, T_1 (absolute control) recorded the shortest length of a cob (18.70 cm). It indicates that there is a positive effect of the combination of microbial consortia and NPK fertilizers, which achieved a good cob formation rate presumably because they enhanced nutrient acquisition and consumption. Similar outcomes are complied with the investigations by Muruganandam *et al*. (2019) [11], on ash gourd and Ravi *et al*. (2017) [14], on marigold. The largest girth of the cobs was observed at harvest in T_8 (100% NPK + microbial consortia; 17.27 cm), in comparison with T_5, (100% NPK, 16.77 cm), and T_7, (75% NPK + microbial consortia, 16.47 cm), and also statistically similar. On the other hand, in T_1 (absolute control) the narrowest girth of the cobs (15.23 cm) was found. The microbial consortium, that contains *Azotobacter*, *B. megaterium* and *Frateuria aurantia* when applied together with the inorganic fertilizers, probably boosted the activity of soil enzymes. This, consequently, could have increased the speed of the mineralization of nutrients and thus enhance nutrient presence and fixation by the crop hence adding to increased cob girth. These statements are in agreement with those made by Jain *et al*. (2021) [6] on wheat and Adey Mourya and Shikha Singh (2022) [1] on pearl millet.

Grain and straw yield

A significant improvement in both grain and straw yield of maize was observed with the application of microbial consortia in combination with NPK fertilizers (Table 4, Fig. 2). Seed inoculation with microbial consortia led to a notable increase in grain yield compared to the control. The highest grain yield (3794.98 kg ha^{-1}) was recorded in treatment T_8 (100% NPK + microbial consortia), followed by T_5 (100% NPK) with 3362.49 kg ha^{-1} and T_7 (75% NPK + microbial consortia) with 3306.87 kg ha^{-1}. The lowest

grain yield (2243.05 kg ha^{-1}) was recorded in the control treatment (T_1). Similarly, straw yield was significantly influenced by the application of microbial consortia. The maximum straw yield (4680.20 kg ha^{-1}) was also recorded in T_8, followed by T_5 (4330.00 kg ha^{-1}) and T_7 (4180.00 kg ha^{-1}), whereas the lowest straw yield (3274.53 kg ha^{-1}) was observed in T_1. These results suggest that the combined use of microbial consortia and NPK fertilizers enhances both grain and biomass production, likely due to improved nutrient uptake and plant growth. The findings are in agreement with Prasad (2022) [12], who also reported increased maize yield with microbial consortia application. Similarly, Mahmud *et al*. (2022) [8] observed enhanced maize grain yield (1987.39 kg ha^{-1}) through integrated use of biofertilizers and mineral fertilizers. Basak *et al*. (2023) [2] reported significantly higher leaf (1682 kg ha^{-1}) and pod (488 kg ha^{-1}) yields in *Senna* with combined use of organic and chemical fertilizers along with microbial consortia. Gote *et al*. (2024) [5] also demonstrated yield improvement in cotton with *Azotobacter chroococcum* and *Bacillus megaterium* applied alongside recommended fertilizer doses.

Table 1: Effect of graded levels of NPK fertilizers and microbial consortia on plant height at tasselling and harvest of maize.

Tr. No.	Treatments	Height of plant (cm)	
		At tasselling stage	At harvest stage
T_1	Absolute control	144.13	150.53
T_2	Microbial consortia	153.27	155.13
T_3	50% NPK	161.60	167.73
T_4	75% NPK	169.80	173.87
T_5	100% NPK	176.27	189.33
T_6	50% NPK + microbial consortia	168.47	169.20
T_7	75% NPK + microbial consortia	172.80	179.73
T_8	100% NPK + microbial consortia	189.60	195.67
	SE(m)±	4.48	2.13
	CD at 5%	13.56	6.46

Table 2: Effect of graded levels of NPK fertilizers and microbial consortia on chlorophyll content of leaves at 30 DAS and 60 DAS of maize.

Tr. No.	Treatments	Chlorophyll content by SPAD meter	
		30 Days	60 Days
T_1	Absolute control	37.15	30.87
T_2	Microbial consortia	42.64	35.53
T_3	50% NPK	46.79	37.34
T_4	75% NPK	47.61	41.88
T_5	100% NPK	53.18	43.11
T_6	50% NPK + microbial consortia	47.01	36.79
T_7	75% NPK + microbial consortia	51.95	42.72
T_8	100% NPK + microbial consortia	53.89	45.92
	SE(m)±	1.45	1.25
	CD at 5%	4.39	3.80

Table 3: Effect of graded levels of NPK fertilizers and microbial consortia on cob length and girth of maize.

Tr. No.	Treatments	Cob length without husk (cm)	Cob girth without husk (cm)
T_1	Absolute control	18.70	15.23
T_2	Microbial consortia	18.80	15.80
T_3	50% NPK	18.83	15.95
T_4	75% NPK	20.23	16.43
T_5	100% NPK	20.97	16.77
T_6	50% NPK + microbial consortia	19.23	15.97
T_7	75% NPK + microbial consortia	20.37	16.47
T_8	100% NPK + microbial consortia	21.17	17.27
	SE(m)±	0.52	0.35
	CD at 5%	1.57	1.08

Table 4: Effect of graded levels of NPK fertilizers and microbial consortia on grain yield and straw yield of maize.

Tr. No.	Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1	Absolute control	2243.05	3274.53
T_2	Microbial consortia	2496.52	3460.50
T_3	50% NPK	2725.91	3710.00
T_4	75% NPK	3120.60	3960.50
T_5	100% NPK	3362.49	4330.00
T_6	50% NPK + microbial consortia	2716.83	3920.00
T_7	75% NPK + microbial consortia	3306.87	4180.00
T_8	100% NPK + microbial consortia	3794.98	4680.20
	SE(m)±	54.40	54.90
	CD at 5%	165.00	166.51

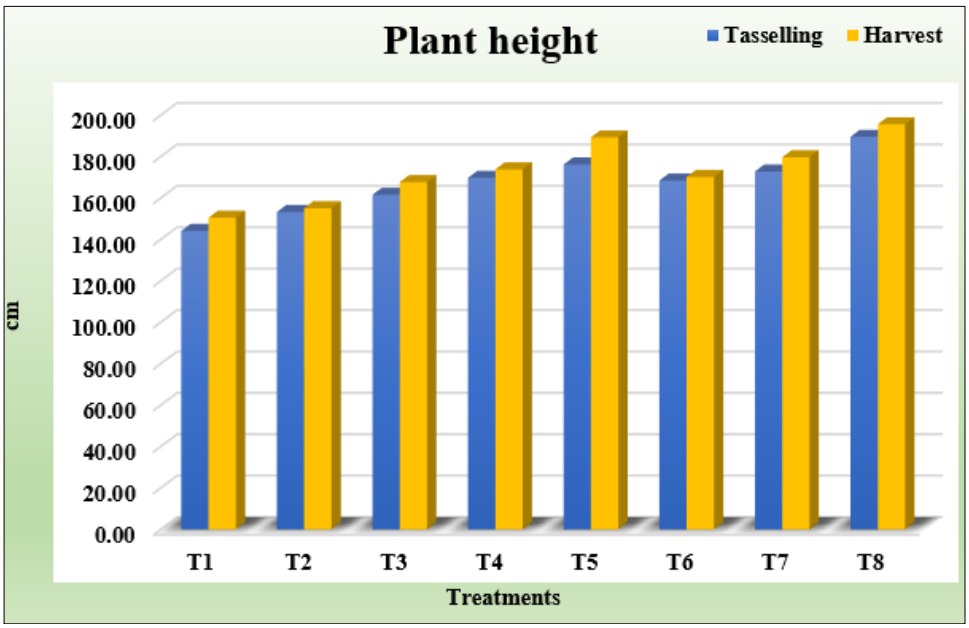

Fig 1: Effect of graded levels of NPK fertilizers and microbial consortia on plant height at tasselling and harvest of maize.

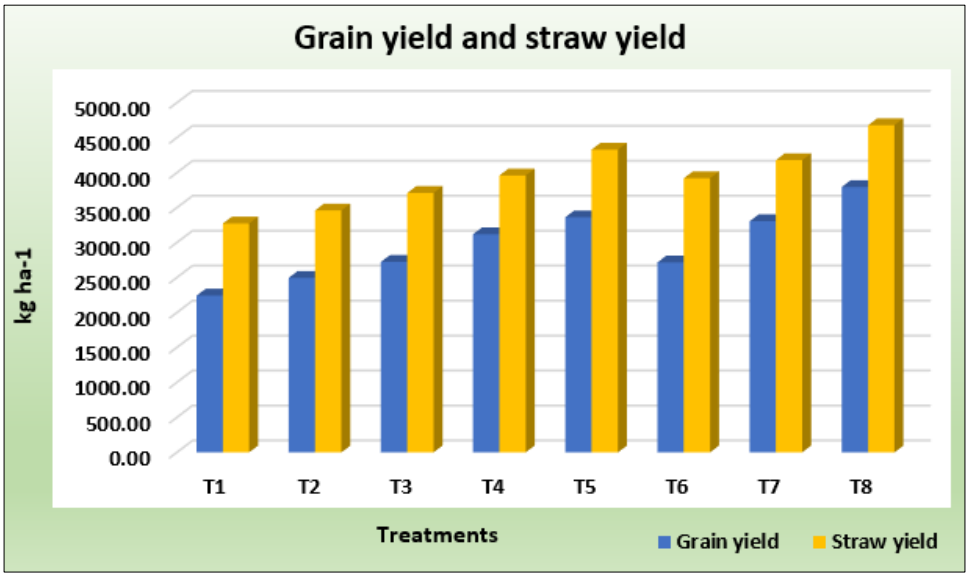

Fig 2: Effect of graded levels of NPK fertilizers and microbial consortia on grain yield and straw yield of maize.

Conclusion

The combination of microbial consortia and NPK fertilizers significantly enhanced the growth and yielding standard of maize. Microbial consortia inoculation of seeds especially when given together with full NPK dosage resulted in high plant height, chlorophyll content, length and girth of cob (without husk). Additionally, such treatment also produced maximum grain and straw yields.

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