E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(6): 01-05
Received: 02-03-2024
Accepted: 01-04-2024

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Effect of biofertilizers and inorganic fertilizers on growth, yield and quality of kharif maize

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i6Sa.788

Abstract
A field experiment was conducted at Agricultural College Farm, Bapatla during 2020 and 2021. To study the "Effect of biofertilizers and inorganic fertilizers on growth, yield and quality of *kharif* maize" The experiment was laid out in randomized block design (RBD) with seven treatments and replicated thrice. The treatments consisted of T_1- Control; T_2- 100% RDF; T_3- 125% RDF; T_4 – 100% RDF + VAM; T_5- 100% RDF +VAM + *Azospirilylum* + PSB; T_6- 75% RDF + VAM; T_7- 75% RDF + VAM + *Azospirillum* + PSB. The results revealed that plant height, drymatter production, grain and stover yield and quality parameters of maize were significantly higher with 100% RDF +VAM + *Azospirillum* + PSB (T_5) and it was on par with T_7 (75% RDF + VAM + *Azospirillum* + PSB), T_3 (125% RDF) and T_4 (100% RDF + VAM). lowest plant height, drymatter production, grain and stover yield and quality parameters are recorded T_1(control) at all three stages of crop growth during both years of study. Present study highlights the need of use of biofertilizers along with inorganic fertilizers to enhance the increased plant height, growth and drymatter production, yield and quality of *kharif* maize. Biofertilizers play significant role in improve plant metabolic activities and increased yield.

Keywords: Biofertilizers, growth, drymatter production, yield and quality parameters

Introduction
Maize *(Zea mays* L.) is one of the important cereal crops next only to wheat and rice in the world. In India, it ranks fourth after rice, wheat and sorghum. Maize is principal staple food in many countries, particularly in the tropics and subtropics and it is being consumed both as food and fodder and also required by the various industries. In India, about 35% of the maize produced is used for human consumption, 25% each in poultry feed and cattle feed and 15% in food processing like corn flakes, popcorn *etc.*, and in other industries mainly starch, dextrose, corn syrup and corn oil etc. The crop has high genetic yield potential hence, it is called Miracle crop and "Queen of Cereals". In India maize is cultivated in 9.86 million hectares and the production and productivity were 31.51 m t and 3195 kg ha^{-1}, respectively and productivity of *kharif* and *rabi* were 2745 kg ha^{-1} and 4908 kg ha^{-1}, respectively. In Andhra Pradesh the area of maize under cultivation is 0.3 m ha, production is 1.95 m t and productivity are 6438 kg ha^{-1} whereas *kharif* and *rabi* maize productivity were 3807 kg ha^{-1} and 8025 kg ha^{-1} respectively (DoES- 2020-21). It is a nutrient exhaustive crop than other cereals and absorbs large quantity of nutrients from the soil during its different growth stages. Maize responds well to fertilizer but under field conditions due to over reliance on nitrogenous fertilizers and no or negligible used of organic manure its yield potential is difficult to exploit. biofertilizers not only help to provide balanced nutrient but also support sustainable production due to their pivotal role in soil health enhancement.

Biofertilizers may help in improving the soil fertility by way of accelerating biological nitrogen fixation from atmosphere, solubilization of the insoluble nutrients already present in soil, decomposing plant residues, stimulating plant growth and production. The process is slow, consumes less energy and provides cheap nutrient to agriculture without polluting the nature. (Pramanik *et al.*, 2012) [14] revealed that inoculation of biofertilizers significantly improved growth parameters like plant height, test weight, grain yield and stover yield.

The main role of the biofertilizers is to mobilize the nutrients present in the soil as they contain those microorganisms. Most importantly the use of biofertilizers is a sustainable way of achieving the desired production as these does not harm available resources. The quality of soil is well maintained by the use of biofertilizers. They can increase the yield up to 30 percent. Biofertilizer show a dynamic and positive effect on crop yield and nutrient uptake by the plant from the soil. There is a difference in biofertilizer performance among different crops out of which climate, soil biodiversity, soil fertility and soil C:N ratio are major contributing factors. Biofertilizer plays a significant role in minimizing the use of synthetic fertilizer by fixing atmospheric nitrogen and increasing P availability to the crop (Selvakumar *et al*., 2012) [16]. The aim of this experiment was to examine the role of biofrtilizers in combination with inorganic fertilizer nutrient sources on growth and yield of maize. Microbial fertilizers can clean the environment, enhance the productive capacity of land and reducing the amount of chemical fertilizer consumption (Hossein and Farshad, 2013) [5] and improve plant growth and health (Raaijmakers *et al*., 2002) [15]. *Azospirillum* species have been potentially studied to the greatest extent and appeared to have significant potential for commercial production (Kumaresan and Reetha, 2011) [9].

Material and Methods

Site Description

The field experiment were carried out during both *kharif* seasons of 2020 and 2021 at Agricultural College Farm, Bapatla. Geographically located at an altitude of 5.49 m above mean sea level, 15°54' North latitude, 80°30' East longitude and about 8 km away from Bay of Bengal. It is located in Krishna agro-climatic zone of Andhra Pradesh. The experimental soil was clay loam in texture, slightly alkaline in reaction (pH 7.56), non-saline (0.64 dS m^{-1}), medium in organic carbon (5.4 g kg^{-1}), medium in available nitrogen (283 kg ha^{-1}), medium in available phosphorus (42.5 kg ha^{-1}), high in potassium (426 kg ha^{-1}) and medium in sulphur (14.3 mg kg^{-1}) and sufficient in all micronutrients (6.81, 5.43, 1.37 and 0.58) (Fe, Mn, Cu and Zn).

Experimental design and treatments

The experiment was laid out in randomized block design (RBD) with seven treatments and replicated thrice. The experimental treatment details are as following T_1- Control; T_2- 100% RDF; T_3- 125% RDF; T_4 – 100% RDF + VAM; T_5- 100% RDF +VAM + *Azospirillum* + PSB; T_6- 75% RDF + VAM; T_7- 75% RDF + VAM + *Azospirillum* + PSB. RDF for maize 200:60:50 kg ha^{-1} N, P_2O_5 and K_2O through applied Urea, SSP and MOP and biofertilizers like VAM -12.5 kg ha^{-1}, *Azospirillum* -5 kg ha^{-1} and PSB -5 kg ha^{-1} through applied vermicompost. The popular hybrid of maize Pioneer 3396 was chosen for the study.

Results and Discussion

Plant height(cm)

The data presented in the table-1 revealed that there was significant influence on plant height (cm) of maize among the treatments at different stages of crop growth during both *kharif* 2020-2021. Persual of data revealed that, as the crop advanced from at kneehigh to harvest, the plant height progressively increased in all the treatments. At all the stages of crop growth, plant height was significantly influenced by the imposed treatment that received T_5 *i.e*., 100% RDF+VAM+*Azospirillum* and PSB (75, 221, 227 cm in 2020 and 81, 228, 235 cm in 2021) recorded significantly highest plant height and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (70, 211, 219 cm and 77, 222, 227 cm),T_3 (125% RDF) (68, 207, 211 cm and 75, 215, 222 cm) and T_4 (100% RDF+VAM) (66, 195, 205 cm and 71, 209, 217cm) at kneehigh, tasseling and harvest stages of maize crop. They were significantly superior over all the treatments during both the years of study, respectively. The lowest plant height was recorded in the treatment T_1 *i.e*., control (47, 154, 163 cm in 2020 and 53, 162, 174 cm in 2021) which received no fertilizers at all the three stages of crop growth. Increase in plant height might be due to combined application of inorganics along with biofertilizers might increase the availability of nutrients in soil as well as promoted the root growth and yield attributing characters. Maize responds very well to the fertilizer application as a result of its well-developed root system which absorbs required nutrients for the effective growth and yield. Positive response to vegetative growth of maize with nitrogen fertilization was also reported by (Liu *et al*., 2018; Zhao *et al*., 2020) [10, 21]. Might be due to continuous supply of essential nutrients throughout the growing period which might have improved plant metabolic activity especially in the early growth stage of the plant. These findings are in conformity with the research outcome of (Prabhavathi *et al*., 2021) [13].

Table 1: Effect of different levels of fertilizers in combination with biofertilizers on plant height(cm) at different stages of maize

Treatments	*Kharif* (2020)			*Kharif* (2021)		
	Kneehigh	Tasseling	Harvest	Kneehigh	Tasseling	Harvest
T_1: Control	47	154	163	53	162	174
T_2: 100% RDF	63	188	195	69	197	205
T_3: 125% RDF	68	207	211	75	215	222
T_4: 100% RDF + VAM	66	195	205	71	209	217
T_5: 100% RDF + VAM+ *Azospirillum* + PSB	75	221	227	81	228	235
T_6: 75% RDF + VAM	59	184	192	66	194	203
T_7: 75% RDF + VAM + *Azospirillum* + PSB	70	211	219	77	222	227
SEm (±)	3.3	9.2	8.6	3.5	9.0	8.5
CD (P=0.05)	10	28	26	11	28	26
CV (%)	8.8	8.1	7.3	8.5	7.6	6.9

Drymatter Production (kg ha^{-1})

The results pertaining to drymatter production was presented in table-2. Significant improvement in drymatter production treated with both inorganics and biofertilizers at different growth stages of maize during *kharif* 2020 and 2021, respectively. Significantly the highest drymatter production was recorded in the treatment received T_5 *i.e*., 100% RDF+ VAM+ *Azospirillum* and PSB (1713, 7152,15482 kg ha^{-1} in 2020 and 1812, 7229, 15681 kg ha^{-1} in 2021) and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (1622,6879,14113 kg ha^{-1} and 1726, 6933,14508 kg ha^{-1}),T_3 (125% RDF) (1533, 6598, 14379 kg ha^{-1} and 1651, 6725, 14414

kg ha^{-1}) and T_4 (100% RDF+VAM) (1522, 6343, 13445 kg ha^{-1} and 1619,6440,13666 kg ha^{-1}) at kneehigh, tasseling and harvest stages of maize crop. They were significantly superior over all the treatments during both the years of study, respectively. The lowest drymatter production was recorded in the treatment T_1 *i.e*., control (995, 4498, 9045 kg ha^{-1} in 2020 and 1044, 4597, 9208 kg ha^{-1} in 2021) which received no fertilizers at all the three stages of crop growth. Drymatter production increased significantly by application of biofertilizers along with inorganic fertilizers. The biofertilizers has the capacity to reduce the leaching losses by fixation of nutrients and converts the unavailable nutrients forms to available forms and increases the nutrient availability to plant which has positive influence on drymatter accumulation in plant. Same results were observed by Iwuagwu *et al*., (2013) [6]. The drymatter production increased gradually at kneehigh to harvest stage due to split application of nitrogen might have improved the NUE (Nitrogen Use Efficiency) (Bairwa *et al*., 2021) [2].

Table 2: Effect of different levels of fertilizers in combination with biofertilizers on drymatter production (kg ha^{-1}) at different stages of maize

Treatments	*Kharif* (2020)			*Kharif* (2021)		
	Kneehigh	Tasseling	Harvest	Kneehigh	Tasseling	Harvest
T_1: Control	995	4498	9045	1044	4597	9208
T_2: 100% RDF	1259	6175	12423	1366	6281	12631
T_3: 125% RDF	1533	6598	14379	1651	6725	14414
T_4: 100% RDF + VAM	1522	6343	13445	1619	6440	13666
T_5: 100% RDF + VAM+ *Azospirillum* + PSB	1713	7152	15482	1812	7229	15681
T_6: 75% RDF + VAM	1206	5899	11188	1287	5925	11392
T_7: 75% RDF + VAM + *Azospirillum* + PSB	1622	6879	14113	1726	6933	14508
SEm (±)	67	314	671	70	306	676
CD (P=0.05)	208	969	2067	217	944	2082
CV (%)	8.3	8.8	9.0	8.1	8.4	8.9

Grain Yield (kg ha^{-1})

The data presented in the table-3 revealed that there was significant influence of combined application of inorganics and biofertilizers to maize crop on grain yield during both years of study. Significantly the highest grain yield was recorded in the treatment received T_5 *i.e*., 100% RDF+ VAM+ *Azospirillum* and PSB (6301 kg ha^{-1} in 2020 and 6500 kg ha^{-1} in 2021) and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (5980 kg ha^{-1} and 6113 kg ha^{-1}), T_3 (125% RDF) (5838 kg ha^{-1} and 6008 kg ha^{-1}) and T_4 (100% RDF+VAM) (5656 kg ha^{-1} and 5850 kg ha^{-1}). They were significantly superior over all the treatments during both the years of study, respectively. The lowest grain yield was recorded in the treatment T_1 *i.e*., control (3874 kg ha^{-1} in 2020 and 4041 kg ha^{-1} in 2021) which received no fertilizers both years of study. The application of biofertilizers increased the efficiency of chemical fertilizers due to control release of nutrients in the soil through microbial activity which might have facilitated better crop growth. Shirkhani and Nasrolahzadeh (2016) [17] observed that combined use of biofertilizers with chemical fertilizers increased the yield and other traits. Therefore, the use of biological fertilizers significantly reduce the consumption of chemical fertilizers and the adverse environmental effects. The improvement in yield and yield traits under integrated use of fertilizers with biofertilizers might be due to higher absorption of nutrients responsible for increased photosynthate accumulation and high biomass production and finally resulting in increase in the yield and yield components. Gundlur *et al.* (2015) [4] and Tomar *et al.* (2017) [18]. A comparatively greater development of plant stature and yield attributes might be possible consequences for higher yields in the treatment which received biofertilizers and inorganics. This was evidenced by significant and positive correlation between higher available N, P, K status and balanced nutrition in the soil of respective treatment and this is in conformity with the findings of (Nayak *et al*., 2020) [11].

Stover Yield (kg ha^{-1})

The data pertaining to the stover yield of maize was presented in the table-3. Shown a significant influence of different treatments imposed during both years of study. Among the results revealed that significantly higher stover yield was recorded in the treatments received T_5 *i.e*., 100% RDF+ VAM+ *Azospirillum* and PSB (8462 kg ha^{-1} in 2020 and 8655 kg ha^{-1} in 2021) and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (8117 kg ha^{-1} and 8270 kg ha^{-1}), T_3 (125% RDF) (7909 kg ha^{-1} and 8021 kg ha^{-1}) and T_4 (100% RDF+VAM) (7631 kg ha^{-1} and 7774 kg ha^{-1}). They were significantly superior over all the treatments during both the years of study, respectively. The lowest stover yield was recorded in the treatment T_1 *i.e*., control (5316 kg ha^{-1} in 2020 and 5408 kg ha^{-1} in 2021) which received no fertilizers during both years of study. The increase in yield may also be attributed to overall improvement in vegetative growth due to better and continuous availability of nutrients at peak growth period and greater synthesis of carbohydrates and their translocation. The increase in straw yield might be due to more amount of nitrogen available through biofertilizers and inorganics. The presence of biofertilizers mainly PSB which increases the availability of phosphorus played an important role in plant biochemical and physiological activities such as photosynthesis, conversion of sugar to starch and genetic characteristics transition, increased P uptake had lead to improved growth and increased photosynthesis and as a result it increased kernel number per cob and thereby kernel yield. This is in accordance with the results reported by (Adnan *et al*., 2018; Zafar *et al*., 2020) [1, 20].

Test weight(g)

The data recorded on test weight of maize presented in table -3 revealed that addition of either inorganics alone or combination with biofertilizers had non-significant effect on test weight of maize kernels during 2020 and 2021. Numerically, higher test weight was recorded in T_5 which received 100% RDF + VAM + *Azospirillum* and PSB (29.76 g in 2020 and 29.81g in 2021) when compared to control. Lowest test weight (23.48 g in 2020 and 23.53 g in 2021) was recorded in the treatment T_1 (control) which received no fertilizers during both years of study. Relatively higher seed weight in the remaining treatments might be ascribed to the supply of biofertilizers and inorganics at higher levels which increase photosynthetic activities and

translocation of photosynthates which might have promoted the growth and there by the improvement in yield attributes which eventually produced a large size of ear head as well as more gain of higher weight that ultimately resulted in a marginal increase in the test weight. Similar findings were also reported by (Kibe and Singh, 2003; Nayak *et al*., 2020) [7, 11].

Table 3: Effect of different levels of fertilizers in combination with biofertilizers on grain, stover yield (kg ha^{-1}) and test weight(g) of maize

Treatments	*Kharif* (2020)			*Kharif* (2021)		
	Grain Yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Test weight (g)	Grain Yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Test weight (g)
T_1: Control	3874	5316	23.48	4041	5408	23.53
T_2: 100% RDF	5301	7112	26.51	5483	7266	26.57
T_3: 125% RDF	5838	7909	27.29	6008	8021	27.35
T_4: 100% RDF + VAM	5656	7631	26.90	5850	7774	26.94
T_5: 100% RDF + VAM+ *Azospirillum* + PSB	6301	8462	29.76	6500	8655	29.81
T_6: 75% RDF + VAM	4858	6652	24.76	4928	6765	24.80
T_7: 75% RDF + VAM + *Azospirillum* + PSB	5980	8117	27.46	6113	8270	27.51
SEm (±)	310	349	1.19	232	347	1.19
CD (P=0.05)	957	1076	NS	714	1069	NS
CV (%)	9.9	8.3	7.73	7.2	8.06	7.71

Quality parameters of maize

Protein content

The results of the experiment pertaining to protein content in maize at harvest stage was significantly influenced by combined application of inorganics and biofertilizers during the both years of study (Table 4). Significantly higher protein content was recorded in treatment received T_5 *i.e.*, 100% RDF + VAM+ *Azospirillum* and PSB (10.83% in 2020 and 11.54% in 2021) and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (9.42% and 9.92%), T_3 (125%RDF) (10.54% and 11.23%) and T_4 (100% RDF+VAM) (10.29% and 10.79%) at harvest stages of maize during 2020 and 2021, respectively. The lowest protein content was recorded in the treatment T_1 *i.e.*, control (7.93% 2020 and 8.25% in 2021) which received no fertilizers. This might be due to combined application of inorganic and biofertilizers which was associated with higher N availability in soil and thereby greater N uptake by crop. Nitrogen, being the principal constituent of protein, might have substantially increased the protein content of the kernel due to increased uptake of nitrogen under higher availability. The effective translocation of photosynthates from source to sink might have further improved the protein in kernels. Similar trend was also reported by (Yadav *et al*., 2016) [19].

Starch content

The data related to starch content in maize was presented in table 4 and the results revealed that at harvest stage of crop, starch content was significantly influenced by different treatments imposed to maize during the both years of study. The highest starch content was recorded in the treatment that received T_5 *i.e.*, 100% RDF + VAM+ *Azospirillum* and PSB (67.02% in 2020 and 68.01% in 2021) and it was on par with the treatments that received T_7 (75% RDF+ VAM + *Azospirillum* and PSB) (66.46% and 67.51%), T_3 (125% RDF) (66.08% and 67.04%) and T_4 (100% RDF+VAM) (65.17% and 66.11%) at harvest stages of maize during 2020 and 2021. The lowest starch content was recorded in the treatment T_1 *i.e.*, control (47.24% 2020 and 48.18% in 2021) which received no fertilizers. Integrated use of inorganics and biofertilizers recorded higher starch content than the treatments which received no fertilizer treatment. Maximum starch content was noticed due to combined application of inorganics and biofertilizers helps in increased microbial load in soil which secrete many growth promoting substances which accelerates the physiological processes like synthesis of carbohydrates. The similar results are obtained by Kumar *et al.* (2018) [8] and Patil *et al.* (2018) [12].

Table 4: Effect of different levels of fertilizers in combination with biofertilizers on protein (%) and starch content (%) of maize

Treatments	*Kharif* (2020)		*Kharif* (2021)	
	Protein Content (%)	Starch Content (%)	Protein Content (%)	Starch Content (%)
T_1: Control	7.93	47.24	8.25	48.18
T_2: 100% RDF	9.43	59.22	9.93	60.30
T_3: 125% RDF	10.54	66.08	11.23	67.04
T_4: 100% RDF + VAM	10.29	65.17	10.79	66.11
T_5: 100% RDF + VAM+ *Azospirillum* + PSB	10.83	67.02	11.54	68.01
T_6: 75% RDF + VAM	9.35	56.36	9.75	57.53
T_7: 75% RDF + VAM + *Azospirillum* + PSB	9.42	66.46	9.92	67.51
SEm (±)	0.43	2.43	0.42	2.48
CD (P=0.05)	1.32	7.49	1.31	7.65
CV (%)	7.52	6.63	7.09	6.70

Conclusion

These results showed that application of biofertilizers along with recommended dose fertilizers increased plant height, drymatter production, yield and quality parameters of *kharif* maize during both years. Application of 100% RDF+VAM+ *Azospirillum* and PSB recorded significantly higher growth, yield and quality of maize due to attributed to better performance through adequate availability of nutrients in soil compare to control.

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