

Effect of Biofertilizers, Levels of Nitrogen and Zinc on Growth and Yield of Hybrid Maize (*Zea mays* L.)

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ABSTRACT

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The experiment consisted of three levels of nitrogen (90,120 and 150 kg ha⁻¹) with basal application of P₂O₅ and K₂O each at 60 kg ha⁻¹ and zinc at 15kg ha⁻¹ (basal application) or 0.5% ZnSO₄ (foliar spray) and inoculated with *Azotobacter* or *Azospirillum*. Highest number of cobs plant⁻¹, plant height, dry weight, grains cob⁻¹ and grain yield was recorded in the plots treated with 150 kg ha⁻¹ N + 15 kg ZnSO₄ basal along with seed inoculation with *Azospirillum* 20 g per kg seeds.

Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as “queen of cereals” because it has the highest genetic yield potential among the cereals. Maize is one of the important cereal crops next to wheat and rice in the world. The productivity of maize mainly depends on its nutrient management (Kumar *et al.*, 2007). Being a C4 plant, maize is capable of utilizing solar radiation more efficiently compared to other cereals. Maize is grown throughout the year in all states of the country for various purposes including fodder for animals, food grain, sweet corn, baby corn, green cobs and popcorn, corn flour is consumed widely in Indian cooking.

Among the cereals in India, maize occupies the third most important food crops after rice and wheat. In order to obtain more agricultural production, either more lands should be cultivated, which is not applicable in most cases, or higher yield must be produced in the currently cultivated lands.

One way is using inoculants of microorganisms which provide many nutrients to plants; *Azotobacter* and *Azospirillum* are the two examples of these microorganisms. Mycorrhizal symbiosis increases absorption of some elements such as phosphorus, nitrogen and micronutrients, improves water uptake, produces hormones, reduces damages caused by environmental stress, improves quality of soil aggregate.

Azotobacter is a beneficial free living (non-symbiosis) nitrogen fixing bacteria which is reported to fix 20-60 kg/ha nitrogen in soil annually. *Azotobacter* was the first and is the most common biofertilizer for some plants such as maize, wheat, sorghum and rice which produces some plant growth promoting metabolites, enzymes and hormones (auxin, cytokinin and gibberelin) in addition to fixing air nitrogen (Forlain *et al.*, 1998).

Nitrogen is an essential element for both fodder quantity and quality as it is a component of protein and chlorophyll. It is thus, essential for photosynthesis, vegetative and reproductive growth and it often determines yield of maize (Iqbal *et al.*, 2006). Both the yield and quality of maize are strongly influenced by the availability of nitrogen.

Application of micronutrient also play significant role in improvement of grain yield of maize. Among micronutrient zinc plays an important role in photosynthesis, nitrogen metabolism and regulates auxin concentration in the plant. The Zn deficiency was found wide spread in Indian soil. Zinc is most crucial amongst the micronutrients that take part in plant growth and development due to its catalytic action in metabolism of almost all crops (George and Schmitt, 2002). However, micronutrients can be applied directly into the soil as well.

Materials and Methods

The experiment was conducted at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during the *Kharif* season of 2016. The soil of the experimental field was sandy loam in texture, acidic in reaction (pH 7.2), low in organic carbon (0.44%), low in available nitrogen (0.99 kg ha⁻¹), medium in available

phosphorus (22.5 kg ha⁻¹) and high in potassium (347 kg ha⁻¹). The experiment consisted of twelve treatment combinations of three levels of nitrogen (90, 120 and 150 kg ha⁻¹), two different biofertilizers (*Azotobacter* seed inoculation and *Azospirillum* seed inoculation), basal application of zinc (15 kg ha⁻¹) and zinc foliar application (0.5 %) with three splits of nitrogen, phosphorus and potassium (each 60kg ha⁻¹) given in basal form. The experiment was laid out in Randomized Block Design and replicated three times. Zinc in the form of ZnSO₄ was applied as basal before sowing of the crop. Recommended dose of nitrogen (120 kg ha⁻¹) as per the treatments was calculated for each plot using urea, along with uniform dose of phosphorus (60 kg ha⁻¹) through diammonium phosphate and potash (60 kg ha⁻¹) through muriate of potash were applied in flat bed a day before sowing of the crop at 5-6 cm depth. One half of the nitrogen along with full dose of phosphorus and potash according to the treatment were applied as basal dose. The remaining half dose of nitrogen was top dressed into equal splits at knee high stage and tasseling stage. The hybrid maize seed “MM 2255” has very early maturity (85 days duration) and sown where seeds were placed at 3-4 cm depth at a spacing of 60 cm between rows and 20 cm between plants. One to two seeds were planted at each hill and covered with soil. The seeds were treated with *Azotobacter* and *Azospirillum* inoculant as per the treatment. The seeds were thoroughly mixed with biofertilizer slurry in such a way that all the seeds were uniformly coated with biofertilizer then allowed to dry in the shade before sowing of the crop.

Results and Discussion

Growth indices of hybrid maize

Maximum plant height was found in treatment receiving seed inoculation of *Azospirillum* + 150 kg ha⁻¹ N + 15 kg ha⁻¹ Zn

(T₆) at 60 DAS recording 148.23 cm and was found to be at par with the application *Azotobacter* + 150 kg ha⁻¹ N + 0.5 % Zn (T₉) and *Azospirillum* + 150 kg ha⁻¹ N + 0.5 % Zn (T₁₂) as shown in Table 1. 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 Braccini *et al.*, (2012) inoculation treatments of maize seeds with liquid *Azospirillum brasilense* 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. Similar findings by Sharma (1973) was reported addition of nitrogen fertilizer increased the plant height. The findings are in full agreement with that of Sawi (1993) and Omara (1989) who observed that nitrogen had significant effects on plant height.

Highest number of plant leaves were observed in treatment T₆ (*Azospirillum* + 150 kg ha⁻¹ N + 15 kg ha⁻¹ Zn) which was found to be statistically at par with T₃ and T₉. At 60 DAS it was found to be statistically at par with treatments T₃ and T₉. Nitrogen fertilization increased number of leaves per plant and leaf area (El Noeman *et al.*, 1990; Gasim, 2001). The findings are in full agreement with that of Sawi (1993) and Omara (1989) who reported that nitrogen had significant effects

on chemical composition of leaves, leaves, internodes number per plant at early stages.

Similarly 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. Carlettie (2002) 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 Carlettie (2002). 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. Braccini *et al.*, (2012) found that inoculation of maize seeds with *Azospirillum brasilense* 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.

Increase in soil nitrogen through fixation by inoculation of *Azotobacter* has increased the crop growth as found by Monib *et al.*, (1979). According to Fallik *et al.*, (1988) the enhancement of root and shoot in *Zea mays* were observed under controlled conditions. Although only relatively small amounts of fertilizers are required during the very early stages of plant growth, high concentration of nutrients in the root zone at that time are beneficial in promoting early growth (Ritchie *et al.*, 1993).

Table.1 Effect of different Biofertilizers, Zinc and Nitrogen levels in Hybrid Maize

Treatments	At 60 DAS			
	Plant height (cm)	Leaves/plant (No.)	Dry weight (g/plant)	CGR (g m ⁻² day ⁻¹)
1. <i>Azotobacter</i> + 90kg/ha N + 15kg/ha Zn	115.67	10.73	17.17	5.27
2. <i>Azotobacter</i> +120kg/ha N + 15kg/ha Zn	121.40	10.67	18.10	5.08
3. <i>Azotobacter</i> + 150kg/ha N+ 15kg/ha Zn	134.67	12.80	22.02	6.61
4. <i>Azospirillum</i> + 90kg/ha N + 15kg/ha Zn	127.00	10.53	18.20	5.53
5. <i>Azospirillum</i> + 120kg/ha N+15kg/ha Zn	130.33	10.73	17.07	5.02
6. <i>Azospirillum</i> + 150kg/ha N+15kg/ha Zn	148.23	13.67	23.10	6.79
7. <i>Azotobacter</i> + 90kg/ha N+ 0.5%Zn	128.60	11.07	17.10	4.98
8. <i>Azotobacter</i> +120kg/ha N+0.5%Zn	133.13	10.87	19.00	5.79
9. <i>Azotobacter</i> +150kg/ha N+0.5%Zn	141.67	13.47	22.03	6.92
10. <i>Azospirillum</i> + 90kg/ha N+0.5%Zn	111.35	10.87	19.07	5.42
11. <i>Azospirillum</i> +120kg/ha N+0.5%Zn	130.73	10.90	20.20	5.89
12. <i>Azospirillum</i> +150kg/ha N+0.5%Zn	140.00	11.10	23.00	6.92
F-test	S	S	S	S
S.Ed. (±)	6.32	0.86	0.13	0.22
C D (P = 0.05)	13.11	1.78	0.27	0.45

Three splits of N and blanket dose of P₂O₅ at 60 kg ha⁻¹ and K₂O at 60 kg ha⁻¹

Table.2 Effect of different Biofertilizers, Zinc and Nitrogen levels in Hybrid Maize

Treatments	At harvest						
	Diameter of cob (cm)	Grain rows cob ⁻¹	No. of grains cob ⁻¹	Grain yield (t/ha)	Stover yield (t/ha)	Net return (Rs ha ⁻¹)	B: C ratio
1. <i>Azotobacter</i> + 90kg/ha N +15kg/ha Zn	11.86	10.00	199.11	3.18	7.30	15403.00	1.45
2. <i>Azotobacter</i> +120kg/ha N+15kg/ha Zn	11.96	12.67	218.89	3.71	8.70	23533.00	1.68
3. <i>Azotobacter</i> +150kg/ha N+15kg/ha Zn	12.59	13.33	251.59	5.00	9.00	40333.00	2.16
4. <i>Azospirillum</i> +90kg/ha N +15kg/ha Zn	11.65	12.67	214.00	3.80	8.70	25003.00	1.73
5. <i>Azospirillum</i> +120kg/ha N+15kg/ha Zn	12.09	13.33	244.86	5.00	9.20	40853.00	2.19
6. <i>Azospirillum</i> +150kg/ha N+15kg/ha Zn	13.09	14.00	323.33	7.90	11.20	80453.00	3.32
7. <i>Azotobacter</i> + 90kg/ha N + 0.5%Zn	12.13	11.33	233.53	4.10	8.40	32573.00	2.00
8. <i>Azotobacter</i> +120kg/ha N + 0.5%Zn	12.05	13.33	264.51	5.38	8.50	49023.00	2.61
9. <i>Azotobacter</i> +150kg/ha N+ 0.5%Zn	12.16	14.00	282.33	6.10	9.20	61733.00	3.20
10. <i>Azospirillum</i> +90kg/ha N+ 0.5%Zn	12.12	11.33	242.00	4.61	9.27	40160.00	2.34
11. <i>Azospirillum</i> +120kg/ha N+ 0.5%Zn	12.21	12.00	319.31	6.60	9.57	66060.00	3.18
12. <i>Azospirillum</i> +150kg/ha N+ 0.5%Zn	12.54	12.67	317.33	6.53	11.00	66423.00	3.17
F-test	NS	S	NS	S	S		
S.Ed. (±)	0.16	1.06	1.73	0.76	0.23		
C D (P = 0.05)	-	2.20	-	1.58	0.48		

Three splits of N and blanket dose of P₂O₅ at 60 kg ha⁻¹ and K₂O at 60 kg ha⁻¹

The data on cob diameter (cm) as influenced by nitrogen management practices with biofertilizers and zinc are presented in Table 2 indicated that the cob diameter was found to be not significant among the other treatments. The highest cob diameter (13.09 cm) was found with the inoculation of *Azospirillum* + 150 kg ha⁻¹ N + 15 kg ha⁻¹ Zn (T₆) and the minimum cob diameter (11.65 cm) was recorded with *Azospirillum* + 90 kg ha⁻¹ N + 15 kg ha⁻¹ Zn (T₄). Some researchers reported different and they found that nitrogen fertilizer application increased the cob diameter values (Kara *et al.*, 1999; Saruhan and Sireli, 2005).

Yield indices of hybrid maize

Grain rows per cob

It is evident from the data presented in the Table 2 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 (T₆) and remained at par to T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₁₀, T₁₁, T₁₂ but significantly superior to T₁.

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.

Grains 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 Mahgoub *et al.*, (2010) and Siam *et al.*, (2008).

Grain yield

Results presented in Table 2 indicated that the highest grain yield of 7.9 t/ha was recorded with combined application of *Azospirillum* + 150 kg ha⁻¹N + 15 kg ha⁻¹ Zn (T₆) and it remained at par to *Azospirillum* + 120 kg ha⁻¹ N + 0.5% Zn (T₁₁) and *Azospirillum* + 150 kg ha⁻¹ N + 0.5% Zn (T₁₂) but significantly superior to rest of the other treatments. This was followed by *Azotobacter* +150 kg ha⁻¹ N + 0.5% Zn (T₉) which is statistically at par to *Azotobacter* +150 kg ha⁻¹ +15 kg ha⁻¹ Zn (T₃), *Azospirillum* + 120 kg ha⁻¹N + 15 kg ha⁻¹ Zn (T₅) and *Azotobacter* +120 kg ha⁻¹ N + 0.5% Zn(T₈). Inoculation with *Azospirillum* resulted in significant yield increases of the magnitude 10 to 30 % (Bashan *et al.*,) Similar findings by Hajnal-Jafari *et al.*, (2012) who indicated that grain yield increased with inoculation by *Azotobacter*. The findings were also similar to Surendra and Sharanappa (2000) who observed that *Azotobacter chroococcum* significantly increased grain yield of maize over no inoculation.

Stover yield

Similar to grain yield, the highest stover yield was observed in *Azospirillum* + 150 kg ha⁻¹N + 15 kg ha⁻¹ Zn (T₆) and was at par

Azospirillum +150 kg ha⁻¹ N + 0.5% Zn (T₁₂) with the value 11.20 t ha⁻¹ and 11 t ha⁻¹, respectively. This was followed by the treatment receiving *Azospirillum* +120 kg ha⁻¹ N + 0.5% Zn (T₁₁) which recorded 9.57 t ha⁻¹ and it remained at par to *Azospirillum* + 120 kg ha⁻¹N + 15 kg ha⁻¹ Zn (T₅), *Azotobacter* +150 kg ha⁻¹ N + 0.5% Zn (T₉) and *Azospirillum* +90 kg ha⁻¹ N + 0.5% Zn (T₁₀) with the value 9.20 t ha⁻¹, 9.20 t ha⁻¹ and 9.27 t ha⁻¹ respectively.

Economics

The total cost of cultivation in the production of hybrid maize was found varied among the different treatments and the highest (Rs 34,567 /ha) as recorded in T₆ and T₃ followed by T₂ and T₅ with the respective values of Rs 34,2267 /ha while the lowest was found in T₉ (Rs 27,687 /ha). Regarding income generated, the highest gross return of Rs 115,020/ha was recorded in T₆ followed by T₁₂ (Rs 96,990 /ha) and T₁₁ (Rs 96,327 /ha). The lowest gross return (Rs 49,370 /ha) was recorded in the treatment T₁. Out of various treatments, application of *Azospirillum* + 150 kg/ha N + 15 kg/ha Zn (T₆) recorded the maximum net profit (Rs 80,453 /ha) which was followed by T₁₂ (Rs 66,423 /ha). The maximum B: C ratio was obtained in T₆ (3.32) which was closely followed by T₉ (3.20). The B: C ratio in treatment T₁ (1.45) was found to be the lowest. The findings were also similar to Chandekar *et al.*, (2005) where cultivation of maize at 60 x 20 cm spacing resulted in higher net return. The findings of Sepat and Kumar (2007) reported that higher yields of green cobs and fodder directly contributed to the returns at higher nitrogen levels.

From the above finding it can be concluded that amongst all the treatments seed treatment with *Azospirillum* in combination with Nitrogen 150 kg ha⁻¹ through Urea along with Zinc 15 kg ha⁻¹ through Zinc sulphate gives

highest plant height at 60 DAS (148.23 cm), number of leaves per plant (13.67), dry weight (23.10 g plant⁻¹) and grain yield (7.9 t/ha) was found to be significantly higher than other varieties significantly. The highest B: C ratio was found in Treatment 6 *i.e.*, 3.32.

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