

EFFECT OF INOCULATION OF AM AND AZOTOBACTER ON N, P, K STATUS OF POST HARVEST SOIL AND UPTAKE BY MAIZE (*ZEA MAYS* L.)

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Abstract: A field experiment was undertaken to find out the effect of inoculation of AM and Azotobacter on N, P, K status on post harvest soil and uptake by maize (*Zea mays* L.) at BAU experimental Farm, Ranchi during rabi season 2015-16 on sandy clay loam soil. The experiment was laid out in a Factorial RBD with three levels of inoculants i.e. Arbuscular Mycorrhiza, Azotobacter and AM + Azotobacter were applied along with four levels of plant nutrients i.e. 0, 50, 75 and 100% recommended dose of fertilizer with combination of 12 treatments: 50% NPK + AM, 50% NPK + Azotobacter, 50% NPK + AM + Azotobacter, 75% NPK + AM, 75% NPK + Azotobacter, 75% NPK + AM + Azotobacter, 100% NPK + AM, 100% NPK + Azotobacter, 100% NPK + AM + Azotobacter, AM alone, Azotobacter alone and AM + Azotobacter, replicated thrice. The initial soil properties was EC (0.149 dSm⁻¹), acidic soil (pH 5.4), low in organic carbon (3.3 g kg⁻¹), available nitrogen (189 kg ha⁻¹), medium in available phosphorus (20 kg ha⁻¹) and available potassium (130 kg ha⁻¹). The results revealed that the application of 100% NPK + AM + Azotobacter significantly increase the available nitrogen (214.7 kg ha⁻¹) and phosphorus (27.9 kg ha⁻¹) in post harvest soil and also increased availability of potassium (153.7 kg ha⁻¹) in soil but not significantly. It also significantly increased total uptake of nitrogen (92.53 kg ha⁻¹) and phosphorus (19.50 kg ha⁻¹) except potassium (83.36 kg ha⁻¹).

Keywords: AM, Azotobacter, Maize, NPK Uptake etc.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in India as well as in the world. It is a miracle crop. There is no cereal on the earth, which has such immense potentiality and that is why it is called "Queen of Cereal". Maize originated in Mexico in Central America. Its introduction in India probably occurred in the beginning of the seventeenth century, during the early days of the East India Company (Patel *et al.*, 2015). Globally maize occupied third position next to wheat and rice in its consumption. In India it is grown on an area about 9.19 m ha with a production 24.18 mt with an average grain yield of 2.63 t ha⁻¹ (Anonymous, 2015 a). Similarly in Jharkhand it is grown on an area of 1.34 m ha with a production of 4.24 mt and an average yield 3.15 t ha⁻¹ (Anonymous, 2015 b). Soil microbes are responsible for critical ecosystem functions such as the biogeochemical cycling of nutrients and organic matter, and the maintenance of plant health and soil quality, Barea *et al.*, (2005a), Barea *et al.*, (2005b); Avis *et al.*, (2008) and Richardson *et al.*, (2009).

AM is a symbiosis between most crops and certain soil fungi. The research on AM fungus and its role in soil and plant has been an interesting scientific subject since 1800. The presence of this fungus in rhizosphere provides with an advantageous and interactive symbiotic relationship between a higher plant root and a nonpathogenic fungus. Through

receiving energetic carbon resources from plant, fungus facilitates the uptake of many inorganic nutrients such as phosphorus, zinc, molybdenum, copper and iron for it. *Azotobacter* is another beneficial microorganism which is a non symbiotic, free living, aerobic nitrogen fixing diazotroph (Wani, 1990). This microorganism results in the secretion of vitamins and amino acids and production of siderophores and auxins which are among the direct mechanisms of increasing root development and plant growth Suneja and Lakshminarayana (1993) and Akbari *et al.*, (2007).

Application of AM and non symbiotic nitrogen fixing bacteria have been shown to enhance soil fertility and availability of nutrients for plants, Cardoso and Kuyper (2006) and to increase photosynthesis and water use efficiency Gosling *et al.*, (2006) and Wu and Xia (2006), and also resistance to biotic and non-biotic stresses (Jeffries *et al.*, 2003). The dual inoculation of asymbiotic N₂ fixer and AM resulted in enhanced root infection, which stimulates plant growth and increased N and P uptake by crops (Zaidi and Khan, 2004). The objective of this study to examine the effect of AM and *Azotobacter* either singly or in combination with different levels of recommended dose of fertilizer on NPK uptake by maize plant (*Zea mays* L.) and nutrient status of the post harvest soil.

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MATERIALS AND METHODS

A field investigation was conducted at BAU experimental Farm, Ranchi during *rabi* season 2015-16 on sandy clay loam soil with EC (0.149 dSm⁻¹), acidic soil (pH 5.4), low in organic carbon (3.3 g kg⁻¹), available nitrogen (189 kg ha⁻¹), medium in available phosphorus (20 kg ha⁻¹), available potassium (130 kg ha⁻¹), exchangeable Ca (3.77 c mol (p⁺) kg⁻¹), Mg (1.24 c mol (p⁺) kg⁻¹) and micronutrient (Zn 1.65; Cu 3.59 and Fe 18.35 mg kg⁻¹). The experiment was laid out in a Factorial Randomized Block Design with 12 treatments replicated thrice: Three levels of inoculants i.e. I₁- AM (*Glomus fasciculatum*), I₂- *Azotobacter* (*Azotobacter chroococcum*) and I₃- AM + *Azotobacter* were applied along with four levels of plant nutrients i.e. F₀- No fertilizer (0%), F₁- 50%, F₂- 75% and F₃- 100% recommended dose of fertilizer. The other package of practices used recommended for raising the crop. The soil and plant analysis was done in laboratory of Department of Soil Science and Agriculture Chemistry, College of Agriculture, BAU, Ranchi.

Soil available nitrogen was determined by using Alkaline paramagnet method (KMnO₄) as described by Subbiah and Asija (1956). The available P (Bray's P_i) was determined by method of Bray and Kurtz (1945) using 0.03 N NH₄F in 0.25 N HCl solution in the extract. Phosphorus was estimated through using spectrophotometer at wavelength 660 nm through colour developed by ascorbic acid blue colour method (Watanabe and Olsen, 1965). Available K was determined by using 1 N NH₄ OAC (pH 7) extractant in soil to solution ratio of 1:10 w/v with the help of Flam Photometer (Elico- CL 361) described by Woodruff and McIntosh (1960). Total N content in grain and straw sample was determined by acid digestion Modified Micro Kjeldal method (Bremner and Mulveney, 1982) and uptake was calculated through Yield. Di-acid digestion Plant material was digested following Procedure as described by Piper (1950). 0.5 gm sample of plant material was taken in conical flasks and 10 ml of Di-acid mixture (HNO₃:HClO₄::10:4) was added. It was heated on a hot plate till complete digestion. The residue was dissolved in redistilled water and final volume was made in 50ml. volumetric flask. The dissolved material was filtered with filter paper. A blank was also carried out in the same way having no plant material. P were estimated by developing Vanadomolybdate yellow colour method (Jackson, 1973) and reading were taken in UV-spectrophotometer (UV-300). K were reading taken in Flam Photometer and Mg was obtained by subtraction to Ca and Mg reading by alternate Versenite Titration method as outlined by Schwarzentach and Biderman and as described by Chopra and Kanwar (1976). Plant uptake was calculated through content and yield. Statistical

analysis and interpretation of results were done by calculating values of C.D. (critical difference) at 5% level of probability through analysis of variance technique as described by Gomez and Gomez (2003).

RESULTS AND DISCUSSION

Available nitrogen

The available nitrogen in soil responded positively with dose of fertilizer with *Arbuscular Mycorrhiza*. Highest mineral nitrogen (205.0 kg ha⁻¹) attained, when AM applied with 75% recommended dose of fertilizer followed by 100% (203.9 kg ha⁻¹) and 50% RDF (187.3 kg ha⁻¹), respectively. However, minimum available nitrogen was recorded when AM was applied with control (171.5 kg ha⁻¹). It is clearly show that the application of AM with 100, 75 and 50% recommended dose of fertilizer is significantly superior over the *Arbuscular Mycorrhiza* alone with no fertilizer treated plot. It is apparent from the data given in the Table 1 that *Azotobacter* showed positive effect on nitrogen availability. the highest nitrogen 208.4 kg ha⁻¹ when it was applied with the 100% recommended dose of fertilizer followed by 75% (200.6 kg ha⁻¹) and 50% (196.3 kg ha⁻¹) recommended dose of fertilizer, respectively and it showed minimum effect on available nitrogen when it was applied with without any dose of fertilizer (173.1 kg ha⁻¹). Application of *Azotobacter* with 100, 75 and 50% recommended dose of fertilizer showed significantly superior over control with *Azotobacter* alone.

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with varying level of fertilizer dose gave various values of available nitrogen in soil which is represented in Table 1. The maximum available nitrogen 214.7 kg ha⁻¹ was recorded when dual inoculums applied with 100% recommended dose of fertilizer followed by 75% (206.2 kg ha⁻¹) and 50% RDF (200.4 kg ha⁻¹). While the minimum amount available nitrogen (185.6 kg ha⁻¹) was recorded in control with dual inoculation. It is clearly indicated that the application of *Arbuscular Mycorrhiza* and *Azotobacter* with 100, 75 and 50% recommended dose of fertilizer is significantly superior over the *Arbuscular Mycorrhiza* alone with control. The interaction effect between inoculation and varying fertilizer dose show positively significant influence on available nitrogen on soil. The best interaction combination resulting increasing the available nitrogen 214.7 kg ha⁻¹ in soil was the use of *Azotobacter* inoculation with recommended dose of fertilizer. It was significantly superior over others. However, the lowest available nitrogen content 171.5 kg ha⁻¹ was noticed in soil obtained from *Azotobacter* treated plot with no fertilizer (control) similar result were also reported by Kucey *et al.*, (1989) Banerjee *et al.*, (2006); Khan and Zaide (2007) and Miri *et al.*, (2013).

Available phosphorus

The available phosphorus in soil responded positively with different dose of fertilizer and AM. Highest mineral phosphorus (26.75 kg ha^{-1}) attained, when *Arbuscular Mycorrhiza* applied with 100% recommended dose of fertilizer followed by 75% (23.66 kg ha^{-1}) and 50% RDF (20.52 kg ha^{-1}), respectively. However, minimum available phosphorus availability was recorded when *Arbuscular Mycorrhiza* applied with no fertilizer (17.47 kg ha^{-1}). It is clearly shown that the application of *Arbuscular Mycorrhiza* with 100, 75 and 50% recommended dose of fertilizer is significantly superior over the *Arbuscular Mycorrhiza* alone with control Miri *et al.*, (2013).

It is apparent from the data given in the Table 2 that *Azotobacter* showed positive effect on phosphorus availability. The highest availability of phosphorus 24.94 kg ha^{-1} was observed when it was applied with the 100% recommended dose of fertilizer followed by 75% (22.09 kg ha^{-1}) and 50% RDF (19.49 kg ha^{-1}), respectively, and it showed minimum effect on available phosphorus when it was applied with or without any dose of fertilizer (16.66 kg ha^{-1}). Application of *Azotobacter* with 100, 75 and 50% recommended dose of fertilizer showed significantly superior over *Azotobacter* and in absence of fertilizer. Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with varying level of fertilizer dose gave significant interaction on available phosphorus which is represented in Table 2. The maximum available phosphorus content 27.89 kg ha^{-1} was recorded when dual inoculums applied with 100% recommended dose of fertilizer followed by 75% (25.60 kg ha^{-1}) and 50% (21.81 kg ha^{-1}) recommended dose of fertilizer, respectively. While the minimum amount of available phosphorus (20.19 kg ha^{-1}) was recorded in control. It is clearly indicated that the application of *Arbuscular Mycorrhiza* and *Azotobacter* with 100, 75 and 50% RDF is significantly superior over mycorrhiza inoculation alone and control. The interaction between inoculation and different dose of fertilizer show positively significant influence on available phosphorus. The highest 27.89 kg ha^{-1} was observed with 100% recommended dose of fertilizer with dual inoculation (AM + *Azotobacter*), however, it was *at par* 26.75 kg ha^{-1} receiving 100% recommended dose of fertilizer with *Azotobacter* alone. The result are in conformity with the study conducted by Kundu and Gaur (1980); Gosh *et al.*, (2004); Khan and Zaide (2007) and Miri *et al.*, (2013)

Available potassium

Inoculation of *Arbuscular Mycorrhiza* alone with varying doses of fertilizers a positive influence on available soil potassium of maize rhizosphere after harvesting was noticed. The maximum available potassium $143.59 \text{ kg ha}^{-1}$ recorded where plot received with AM + 100% recommended dose of fertilizer and followed by 125.12 and $111.25 \text{ kg ha}^{-1}$

in *Arbuscular Mycorrhiza* with 75% and 50% recommended dose of fertilizer, respectively. However, all these three treatments were superior over AM without fertilizer treated plot ($103.12 \text{ kg ha}^{-1}$). Application of different levels of fertilizers with *Azotobacter* incorporation did show significant variation on available potassium of soil. However, *Azotobacter* with 100% recommended dose of fertilizer application attained highest available potassium ($139.48 \text{ kg ha}^{-1}$), followed by 75% ($115.01 \text{ kg ha}^{-1}$) and 50% RDF ($109.80 \text{ kg ha}^{-1}$), respectively. While all these three treatments show superior over mycorrhiza inoculation and no fertilizer treated plot (91.84 kg ha^{-1}). The maximum available potassium in post harvest soil $153.67 \text{ kg ha}^{-1}$ was recorded when plot received 100% recommended dose of fertilizer with dual inoculation, followed by 75% ($136.84 \text{ kg ha}^{-1}$) and 50% ($116.72 \text{ kg ha}^{-1}$) recommended dose of fertilizer, respectively. While the minimum available potassium $113.84 \text{ kg ha}^{-1}$ was recorded in plot that received control with dual inoculation of AM and *Azotobacter* (Table 3). The interaction between inoculation and different doses of fertilizer did not show significant response on available potassium in maize rhizosphere. Banerjee *et al.*, (2006).

Total nitrogen uptake

Observation recorded in Table 4 on total nitrogen uptake of maize (grain + straw) as influenced by various level of fertilizer dose with *Arbuscular Mycorrhiza* and *Azotobacter* inoculation has significantly affect the uptake of plant. Signification differences in total nitrogen uptake of maize due to imposition of progressive fertilizer dose with *Arbuscular Mycorrhiza* inoculation were observed at maturity. Highest total nitrogen uptake 80.45 kg ha^{-1} was noted in soils receiving inoculation of AM with 100% recommended dose of fertilizer, it was followed by 70.43 and 52.39 kg ha^{-1} in presence of *Arbuscular Mycorrhiza* with 75% and 50% recommended dose of fertilizer, respectively. All the different levels of fertilizer treatments (100, 75 and 50% RDF) varied significantly among themselves and also over *Arbuscular Mycorrhiza* alone treated plot (19.77 kg ha^{-1}) Yao and Li, 1999. It is apparent from the Table 4 that as *Azotobacter* with different dose of fertilizers increasing, the total nitrogen uptake also increased significantly. Highest total nitrogen uptake 79.29 kg ha^{-1} was noted in soils receiving inoculation of *Azotobacter* with 100% recommended dose of fertilizer, it was followed by 67.46 and 55.51 kg ha^{-1} in presence of *Azotobacter* with 75% and 50% RDF, respectively. Application of different doses of fertilizer significantly varied among themselves and over without fertilizer treatment. The least nitrogen uptake 18.70 kg ha^{-1} was recorded with control and *Azotobacter* alone treated plot. It is clear from the Table 4 that the dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with various levels of fertilizer dose gave significant variation on total nitrogen uptake.

The maximum 92.53 kg ha⁻¹ total nitrogen uptake was observed with 100% recommended dose of fertilizer, followed by 78.02 and 68.06 kg ha⁻¹ with 75% and 50% recommended dose of fertilizer, respectively. All fertilizer doses showed significant variation among themselves and over the control i.e. 29.69 kg ha⁻¹. The interaction effect between inoculation with varying fertilizer dose indicated the test plant to have attained significant higher nitrogen uptake in plant parts compared to individual application of either AM or *Azotobacter* inoculation. Rest of the interaction was found to have significant influence on total nitrogen uptake were reported by Radwan, (1998); Somani, (2002); Khan and Zaide (2007) and Sharif *et al.*, (2012).

Total phosphorus uptake

The Table 5 indicated that the significant differences in total phosphorus uptake by maize due to addition of progressive fertilizer dose with inoculation of AM were observed at maturity. Highest total phosphorus uptake 15.67 kg ha⁻¹ was noted in soils receiving inoculation of AM with 100% recommended dose of fertilizer, it was followed by 11.73 kg ha⁻¹ and 7.94 kg ha⁻¹ in presence of AM with 75% and 50% recommended dose of fertilizer, respectively. All the treatments varied significantly among themselves and also over AM alone treated plot i.e. 2.78 kg ha⁻¹, Krishna and Bagyaraj, (1982) It is apparent from the Table 5 that as *Azotobacter* supplemented with dose of fertilizers increasing, the total phosphorus uptake also increased significantly. Maximum total phosphorus uptake 13.52 kg ha⁻¹ was noted in soils receiving inoculation of *Azotobacter* with 100% recommended dose of fertilizer, it was followed by 8.72 and 6.88 kg ha⁻¹ in presence of *Azotobacter* with 75% and 50% RDF, respectively. All the other treatments varied significantly among themselves and also over *Azotobacter* alone treated plot (2.34 kg ha⁻¹).

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with various levels of fertilizer dose, enhanced better phosphorus utilization by the plants noted when the plants were grown in presence of different level recommended dose of fertilizer. The maximum 19.50 kg ha⁻¹ total phosphorus uptake was observed with 100% recommended dose of fertilizer, followed by 14.62 and 11.46 kg ha⁻¹ with 75% and 50% RDF, respectively. The lowest phosphorus uptake 4.26 kg ha⁻¹ were observed when plot received only inoculation (AM + *Azotobacter*). The interaction effect between inoculation and different dose of fertilizer indicated that the highest phosphorus 19.50 kg ha⁻¹ was observed in plant with 100% recommended dose of fertilizer along with dual inoculation (AM + *Azotobacter*). However, it was followed by 15.67 kg ha⁻¹ with 100% recommended dose of fertilizer along with mycorrhizal inoculation similar finding were also reported by Clark and Zeto, (2000); Shivputra *et al.*,

(2004); Behl *et al.*, (2003); Smith and Read, 2008; Javaid, 2009 and Miri *et al.*, (2013).

Total potassium uptake

The *Arbuscular Mycorrhiza* inoculation has maximum impact on potassium content and uptake by maize, when it was applied with 100% recommended dose of fertilizer. Total potassium uptake was recorded maximum 73.17 kg ha⁻¹ in case of 100% recommended dose of fertilizer + AM and it was superior over 62.46 and 43.19 kg ha⁻¹ with 75% and 50% recommended dose of fertilizer, respectively. All these treatments also showed significant superiority over the control and least with *Arbuscular Mycorrhiza* inoculation alone i.e. 16.60 kg ha⁻¹. It is clear from the Table 6 that the total potassium uptake responded positively with increasing dose of fertilizer with *Azotobacter* inoculation. Total potassium uptake recorded maximum when *Azotobacter* applied with 100% recommended dose of fertilizer (66.60 kg ha⁻¹) and followed by 75% (51.93 kg ha⁻¹) and 50% RDF (40.40 kg ha⁻¹). Total potassium uptake recorded minimum (14.09 kg ha⁻¹) when plot received *Azotobacter* inoculation without chemical fertilizer. Dual inoculums of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose responded significantly on total potassium uptake which is represented in the Table 6. The maximum total potassium uptake 83.36 kg ha⁻¹ was recorded in treatment receiving 100% recommended dose of fertilizer + AM + *Azotobacter* and followed by 75% (72.39 kg ha⁻¹) and 50% RDF (59.45 kg ha⁻¹), respectively. All these treatment also showed significantly superior over the control and minimum with *Azotobacter* alone (24.36 kg ha⁻¹) treated plot. The interaction effect between inoculation and different doses of fertilizer failed to bring any significant changes on total potassium uptake of maize. These results are in close conformity with the findings of Khan and Zaide (2012) and Miri *et al.*, (2013).

CONCLUSION

NPK content in soil significantly increasing by application different dose of RDF with dual inoculants in maize. Although the available nitrogen and potassium noted in low status in post harvest soil but phosphorus content was recorded in medium categories. Nitrogen and phosphorus content of plant significantly increased by application of microbial inoculation and different doses of NPK. The biofertilizers and chemical fertilizer inputs also showed significant and positive effect on uptake of nutrients by grain and straw, uptake was minimum in control and highest at 100 and 75 % RDF. Use of 75 and 100% level per hectare maintained uptake significantly *at par* microbial inoculation helped in maintain higher uptake of N and P grain and straw than control. Uptake of potassium by grain and straw

were significantly enhanced with increasing level of NPK with AM and *Azotobacter* inoculation. Thus, based on aforesaid conclusion, it is inferred that for increasing productivity of maize in acidic soil of Ranchi (Jharkhand), Dual microbial inoculation

(Mycorrhiza and *Azotobacter*) along with balance dose of fertilizer (RDF) will not only be beneficial for the farmers but also maintaining a good soil health (improving the biological condition of the soil).

Table 1. Effect of inoculation and nutrient combinations on soil available nitrogen (kg ha⁻¹) in maize rhizosphere

Inoculation	Fertilizer				
	F ₀	F ₁	F ₂	F ₃	Mean
I ₀	171.5	187.3	205.0	203.9	191.9
I ₁	173.1	196.3	200.6	208.4	194.6
I ₂	185.6	200.4	206.2	214.7	201.7
Mean	176.7	194.7	203.9	209.0	

Initial: 189 kg ha⁻¹

Factor	S.Em(±)	CD (P =0.05)
I	1.43	4.37
F	2.01	5.98
I X F	3.36	9.94
C.V. (%) :	4.78	

Table 2. Effect of inoculation and nutrient combinations on soil available phosphorus (kg ha⁻¹) in maize rhizosphere

Inoculation	Fertilizer				
	F ₀	F ₁	F ₂	F ₃	Mean
I ₁	17.47	20.52	23.66	26.75	22.10
I ₂	16.66	19.49	22.09	24.94	20.79
I ₃	20.19	21.81	25.60	27.89	23.87
Mean	18.11	20.61	23.78	26.52	

Initial: 20.38 kg ha⁻¹

Factor	S.Em(±)	CD (P =0.05)
I	0.33	0.98
F	0.38	1.13
I X F	0.66	1.95
C.V. (%) :	5.79	

Table 3. Effect of inoculation and nutrient combinations on soil available potassium (kg ha⁻¹) in maize rhizosphere

Inoculation	Fertilizer				
	F ₀	F ₁	F ₂	F ₃	Mean
I ₁	103.12	111.25	125.12	143.59	120.77
I ₂	91.84	109.80	115.01	139.48	114.03
I ₃	113.84	116.72	136.84	153.67	130.27
Mean	102.93	112.59	125.66	145.58	

Initial: 130.37 kg ha⁻¹

Factor	S.Em(±)	CD (P =0.05)
I	1.79	5.24
F	2.06	6.06
I X F	3.58	NS
C.V. (%) :	4.53	

Table 4. Effect of inoculation and nutrient combinations on nitrogen content and uptake (grain + straw) in maize.

Treatment	N-Content in Grain (%)	N-Uptake by Grain (Kg ha ⁻¹)	N-Content in Straw (%)	N-Uptake by Straw (Kg ha ⁻¹)	Total N Uptake (Kg ha ⁻¹)
F ₀ I ₀	1.12	8.62	0.36	11.15	19.77
F ₀ I ₁	1.15	8.05	0.38	10.65	18.70
F ₀ I ₂	1.27	13.59	0.41	16.10	29.69
F ₁ I ₀	1.18	29.50	0.40	22.89	52.39
F ₁ I ₁	1.24	29.39	0.43	26.12	55.51
F ₁ I ₂	1.32	38.94	0.46	29.12	68.06
F ₂ I ₀	1.27	42.42	0.44	28.01	70.43
F ₂ I ₁	1.29	38.70	0.47	28.76	67.46
F ₂ I ₂	1.29	46.31	0.47	31.71	78.02
F ₃ I ₀	1.27	48.39	0.46	32.06	80.45
F ₃ I ₁	1.29	46.83	0.48	32.46	79.29
F ₃ I ₂	1.30	56.81	0.48	35.72	92.53

I

CD (P =0.05) 0.02 1.53 0.02 1.57 3.65

F

CD (P =0.05) 0.03 1.71 0.02 1.69 3.84

I × F

CD (P =0.05) 0.05 3.16 0.04 2.21 7.37

C.V. (%) **4.20** **5.72** **5.22** **7.15** **8.9****Table 5.** Effect of inoculation and nutrient combinations on phosphorus content and uptake (grain + straw) in maize.

Treatment	P-Content in Grain (%)	P-Uptake by Grain (Kg ha ⁻¹)	P-Content in Straw (%)	P-Uptake by Straw (Kg ha ⁻¹)	Total P Uptake (Kg ha ⁻¹)
F ₀ I ₀	0.23	1.75	0.03	1.02	2.78
F ₀ I ₁	0.21	1.48	0.03	0.86	2.34
F ₀ I ₂	0.25	2.70	0.04	1.57	4.26
F ₁ I ₀	0.23	5.71	0.04	2.23	7.94
F ₁ I ₁	0.21	4.89	0.03	1.98	6.88
F ₁ I ₂	0.28	8.13	0.05	3.33	11.46
F ₂ I ₀	0.27	9.14	0.04	2.59	11.73
F ₂ I ₁	0.23	6.89	0.03	1.83	8.72
F ₂ I ₂	0.30	10.73	0.06	3.83	14.56
F ₃ I ₀	0.31	11.65	0.06	4.02	15.67
F ₃ I ₁	0.28	10.29	0.05	3.23	13.52
F ₃ I ₂	0.32	13.98	0.07	5.52	19.50

I

CD (P =0.05) 0.22 0.62 0.01 0.19 0.62

F

CD (P =0.05) 0.05 0.64 0.01 0.28 0.84

I × F

CD (P =0.05) 0.09 0.86 0.02 0.43 1.26

C.V. (%) **6.07** **8.11** **7.50** **5.17** **7.25**

Table 6. Effect of inoculation and nutrient combinations on potassium content and uptake (grain + straw) in maize.

Treatment	K-Content in Grain (%)	K-Uptake by Grain (Kg ha ⁻¹)	K-Content in Straw (%)	K-Uptake by Straw (Kg ha ⁻¹)	Total K Uptake (Kg ha ⁻¹)
F ₀ I ₀	0.20	1.51	0.49	15.09	16.60
F ₀ I ₁	0.18	1.27	0.46	12.82	14.09
F ₀ I ₂	0.23	2.47	0.56	21.88	24.36
F ₁ I ₀	0.26	6.42	0.64	36.77	43.19
F ₁ I ₁	0.23	5.44	0.58	34.96	40.40
F ₁ I ₂	0.27	7.92	0.81	51.52	59.45
F ₂ I ₀	0.25	8.38	0.85	54.08	62.46
F ₂ I ₁	0.24	7.32	0.73	44.61	51.93
F ₂ I ₂	0.28	10.17	0.92	62.23	72.39
F ₃ I ₀	0.28	10.67	0.90	62.51	73.17
F ₃ I ₁	0.27	9.65	0.84	56.95	66.60
F ₃ I ₂	0.31	13.67	0.94	69.69	83.36

I**CD (P =0.05)** 0.02 0.49 0.03 2.21 3.52**F****CD (P =0.05)** 0.03 0.54 0.04 2.49 3.78**I × F****CD (P =0.05)** NS NS NS NS NS**C.V. (%)** **5.09** **8.41** **4.57** **7.53** **8.25****REFERENCES**

Akbari, G.A., Arab, S.M., Alikhani, H.A., Allahdadi, I. and Arzanesh, M.H. (2007) Isolation and selection of indigenous *Azospirillum spp.* and the IAA of superior strains effects on wheat roots. *World Journal of Agricultural Sciences*, **3**(4): 523-529.

Anonymous (2015a). <https://www.indiastat.com/table/agriculture/2/maize/17199/7269/data>.

Anonymous (2015b). <https://www.indiastat.com/table/agriculture/2/maize/17199/454876/data>.

Avis, T.J., Gravel, V., Antoun, H. and Tweddell, R.J. (2008), Multifaceted beneficial effects of rhizosphere microorganisms on plant health and productivity. *Soil Biology and Biochemistry*, **40**: 1733-1740.

Banerjee, M., Rai, R. K., Debtanu M. and Dhas, S. (2006), Impact of chemical fertilizers and bio-fertilizers on yield and fertility build-up of soil under maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agriculture Sciences*, **76**(12): 753-755.

Barea, J.M., Azcón, R. and Azcón-Aguilar, C. (2005a), Interactions between Mycorrhizal Fungi and Bacteria to Improve Plant Nutrient Cycling and Soil Structure. In: Buscot, F., Varma, A. (Eds.),

Microorganisms in Soils: Roles in Genesis and Functions, Springer-Verlag, Berlin, Heidelberg, pp195-212.

Barea, J.M., Pozo, M.J., Azcón, R. and Azcón-Aguilar, C. (2005b), Microbial co-operation in the rhizosphere. *Journal of Experimental Botany*, **56**: 1761-1778.

Behl, R.K., Sharma, H., Kumar, V. and Narula, N. (2003), Interaction amongst mycorrhiza, *Azotobacter chroococcum* and root characteristics of wheat varieties. *J. Agron. Crop Sci.*, **189**: 151-155.

Bray, R.H. and Kurtz, L.T. (1945), Determination of total organic and available form of phosphorus in soil. *Soil Science*, **59**: 39-45.

Bremner, J.M. and Mulvaney, C.S. (1982), Nitrogen-Total. In: Page, A.L., H. Miller and D.R. Keeney (eds.), *Methods of Soil Analysis*, Part II, pp: 56–69. Agron. Monogram No. 9, American Society Agron., Wisconsin, USA.

Cardoso, I. M. and Kuyper, T.W. (2006), Mycorrhizas and tropical soil fertility. *Agric. Ecosys. Environ.*, **116**: 72-84.

Clark, R.B., Baligar, V.C. and Zobel, R.W. (2005), Response of mycorrhizal switchgrass to phosphorus fractions in acidic soil. *Communications in Soil Science and Plant Analysis*, **36** (9-10): 1337-1359.

Ghosh, P.K., Ramesh, P., Bandyopadhy, K.K., Tripathi, A.K., Hati, K.M. and Misra, A.K.

- (2004), Comparative Effectiveness of Cattle Manure, Poultry Manure, Phosphocompost and Fertilizer-NPK on Three Cropping Systems in Vertisols of Semi-arid Tropics. I. Crop Yields and Systems in Performance. *Bioresource Technology*, **95**: 77-83.
- Gomez, K.A. and Gomez, A.A.** (2003), *Statistical Procedure for Agricultural Research*. John Wiley and Sons, London, U.K. pp. 139-167 and 204-207.
- Gosling, P., Hodge, A., Goodlassm G. and Bending, G.D.** (2006), Arbuscular mycorrhizal fungi and organic farming. *Agric. Ecosys. Environment*, **113**: 17-35.
- Jackson, M. K.** (1973), *Soil chemical analysis*. Prentice-Hall. Inc. Engle Wood Cliffs, New Jersey.
- Javaid, A.** (2009), Mycorrhizal mediated nutrition in plants. *J. Plant Nut.*, (in press).
- Jeffries, P., Gianinazzi, S., Perotto, S., Turnau, K. and Barea, J.M.** (2003), The contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. *Biol. Fertil. Soils*, **37**: 1-16.
- Khan, M.S. and Zaidi, A.** (2007), Synergistic effects of the inoculation with plant growth promoting rhizobacteria and an *Arbuscular mycorrhizal* fungus on the performance of wheat. *Agriculture and forestry*, **31**(16): 355-362.
- Krishna, K.R. and Bagyaraj, D.J.** (1982), Effect of *Vesicular Arbuscular Mycorrhize* and soluble phosphate on *Ablemoschus esculentus* (L.) Moench. *Plant and Soil*, **64**(2): 209-213.
- Kucey, R.M.N., Janzen, H.H. and Legget, M.E.** (1989), Microbial mediated increase in plant available phosphorus. *Advances of Agronomy*, **42**: 199-228.
- Kundu, B.S. and Gaur, A.C.** (1980), Establishment nitrogen fixing and phosphate solubilizing bacteria in rhizosphere and their effect on yield and nutrient uptake of wheat crop. *Plant Soil*, **57**: 223-230.
- Miri, M. R., Moghadam, H. R. T., Ghooshchi, F. and Zahedi, H.** (2013), Effect of *Azotobacter* and *Arbuscular Mycorrhizal* Colonization Enhance Wheat Growth and Physiological Traits Under Well-Watered and Drought Conditions. *Advances in Environmental Biology*, **7**(14): 4630-4636.
- Patel, R., Deshpande, R. M., Toncher, S. S. and Sapkal, S. A.** (2015), Nutrient uptake and soil fertility by maize as influenced by detasseling and nutrient management. *Plant Archives*, **15** (1): 137-141.
- Piper, C.S.** (1950), *Soil and plant Analysis*, New York Academic Press.
- Radwan, F.I.** (1998), Response of some maize cultivars to VA-mycorrhizal inoculation, biofertilization and soil nitrogen application. *Alexandria J. Agric. Res.*, **43** : 43-56.
- Richardson, A.E., Barea, J.M., McNeill, A.M. and Prigent-Combaret, C.** (2009), Acquisition of phosphorus and nitrogen in the rhizosphere and plant growth promotion by microorganisms. *Plant and Soil*, **321**: 305-339.
- Sharif, M., Saud, S., Burni, T., Afzal, M., Khan, F., Khan, M. J. and Wahid, F.** (2012), Effect of *Arbuscular Mycorrhizal* fungal inoculation in combination with different organic fertilizers on maize crop in eroded soils. *Pak. J. Bot.*, **44**(4): 1427-1432.
- Shivaputra, S. S., Patil, C. P., Swamy, G. S. K. and Patil, P. B.** (2004), Cumulative effect of VAM fungi and vermicompost on nitrogen, phosphorus, potassium and chlorophyll content of papaya leaf. *Mycorrhiza News*, **16**(2): 15-16.
- Smith, S.E. and Read, D.J.** (2008), *Mycorrhizal Symbiosis*, third ed. Academic Press, New York. Elsevier.
- Somani, L.L.** (2002), *Phosphatic biofertilizer*. Agrotech Publishing Academy, Udaipur, 224pp.
- Subbiah, B.V. and Asija, G.L.** (1956), A rapid procedure of the determination of available nitrogen in soil. *Current Science*, **25**, 259-260.
- Suneja, S. and Lakshminarayana, K.** (1993), Production of hydroxamate and catechol siderophores by *A. chroococcum*. *Indian Journal of Experimental Biology*, **31**: 878-881.
- Wani, S.P.** (1990), Inoculation with associative nitrogen fixing bacteria in cereal grain production improvement. *Indian Journal of Microbiology*, **30**: 363-393.
- Watanabe, F.S. and Olsen, S.R.** (1965), Test of ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts of soil. *Proc. Soil Sci. Soc. Am.*, (29):677-678.
- Woodruff, C.M. and McIntosh, J.L.** (1960), Testing for soil potassium. *Trans 7th Intern. Congr. Soil Sci. Madison*, (3): 80-85.
- Wu, Q.S. and Xia, R.X.** (2006), *Arbuscular Mycorrhizal* fungi influence growth, osmotic adjustment and photosynthesis of citrus under well-watered and water stress conditions. *Journal of Plant Physiology*, **163**: 417-425.
- Yao, Q. and Li, D.** (1999), Influence of VA mycorrhiza on juice components and arid colour of *Citrus fruit*. *J. fruit. Sc. China*, **16** : 38 – 42.
- Zaidi, A. and Khan, M.S.** (2004), Bioassociative effect of rhizospheric microorganism on growth, yield and nutrient uptake of green gram. *J. Plant Nutr.*, **27**: 599-610.