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EFFICIENCY OF INOCULATION WITH AM AND *AZOTOBACTER* ON AGRONOMIC CHARACTERISTICS AND YIELD OF MAIZE (*Zea mays* L.)

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ABSTRACT
A field investigation was conducted at BAU experimental Farm, Ranchi during *rabi* season 2015-16 on sandy clay loam soil. The experiment was laid out in a Factorial Randomized Block Design with 12 treatments replicated thrice. The results revealed that the growth parameters and yield attributes such as plant height (214.4 cm) and shoot dry weight (236.2 g^{-1}), no. of cobs/plant (1.33), no. of row/cobs (15.1) cob weight (172.8 g cob) and cob length (18.3 cm) was recorded maximum when plot received balanced dose of fertilizer with dual inoculation of AM and *Azotobacter*. Application of AM + *Azotobacter* inoculation with 100% RDF significantly increased the grain yield (43.7 q ha^{-1}) and stover yield (64.9 q ha^{-1}). The harvest index ranged between 19.9 to 36.9 % of maize. The grain and stover yield was recorded lowest when plot received 0, 50 and 75% recommended dose of plant nutrient along with microbial inoculation alone.

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. It contributes about 20 per cent of the world's total cereal production. It is one of the most versatile crops in nature, which can be grown over a wide range of climatic conditions and has acquired a dominant role in the farming sector. Maize is a very popular crop in India because of the increasing market price and high production potential in both irrigated as well as rainfed conditions. 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).

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. Efforts to produce inoculants from AM fungi and to use it in proper environmental conditions, is a significant environmental friendly way to help plant growth and development through the enhancement of this natural phenomenon (Mehrvarz *et al.*, 2008). *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). The production of siderophore which solubilize Fe^{+3} and suppress plant pathogens through iron deprivation, *Azotobacter* also produces Thiamin, Riboflavin, Indole Acetic Acid and Gibberellins (Kader *et al.*, 2002).

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 N_2 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 growth, yield attributes and yield of maize (*Zea mays* L.).

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. I_1- AM (*Glomus fasciculatum*), I_2- *Azotobacter* (*Azotobacter chroococcum)* and I_3- AM + *Azotobacter* were applied along with four levels of plant nutrients *i.e.* F_0- No fertilizer (0%), F_1- 50%, F_2- 75% and F_3- 100% recommended dose of fertilizer. The other package of practices used recommended for raising the crop. 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

Plant height

Inoculation of *Arbuscular Mycorrhiza* alone with varying doses of fertilizers is a positive influence on plant height at maturity. The maximum plant height 208.2 cm was recorded with AM + 100% recommended dose of fertilizer and followed by 75% (204.8 cm) and 50% AM (196.3 cm), respectively. However, all these three treatment were superior over AM alone with control (158.2 cm) treated plot (Table 1).

Application of varying levels of fertilizers with *Azotobacter* incorporation did not show any significant variation on plant height. However, *Azotobacter* with 100% recommended dose of fertilizer application attained maximum plant height (202.5 cm), followed by 75% (200.1 cm) and 50% (187.3 cm) RDF, respectively. While all these three treatments showed superiority over *Arbuscular Mycorrhiza* alone with control (157.0 cm) similar findings were also reported by Soleimanzadeh and Gooshchi (2013).

Similarly, dual inoculation of AM and *Azotobacter* with different levels of fertilizer. The maximum plant height 214.4 cm was recorded when plot received 100% recommended dose of fertilizer with dual inoculation, followed by 75% (205.5 cm) and 50% (199.9 cm) recommended dose of fertilizer with both *Arbuscular Mycorrhiza* and *Azotobacter* inoculations, respectively. While minimum plant height 164.6 cm was recorded in plot that received no fertilizer with dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* only (Charantimath and Lakshman, 2007). The interaction effect between inoculation and varying fertilizer dose did not show significant influence on plant height of maize at maturity similar result were also reported by Bahrani *et al*. (2010), Seyedlar *et al*. (2014).

Shoot dry weight

The addition of *Arbuscular Mycorrhiza* in test plant has shown positive effect on shoot dry weight, when it was applied with 100% recommended dose of fertilizer. Shoot dry weight was recorded maximum 224.5 g^{-1} with 100% recommended dose of fertilizer + AM and it was superior over 75% and 50% RDF (186.6 and 161.7 g^{-1}), respectively. All these treatments also showed significant superiority over the control with *Arbuscular Mycorrhiza* alone (131.5 g^{-1}).

Application of *Azotobacter* helped the test plant to attain higher shoot dry weight in presence of *Azotobacter* inoculation in each plot, The highest shoot dry weight was recorded *Azotobacter* with 100% recommended dose of fertilizer (205.4 g^{-1}), followed by 75% (168.0 g^{-1}) and 50% RDF (144.8 g^{-1}),

Table 1: Effect of inoculation and nutrient combinations on plant height (cm) of maize.

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	158.2	196.3	204.8	208.2	191.9
I_2	157.0	187.3	200.1	202.5	186.7
I_3	164.6	199.9	205.5	214.4	196.1
Mean	159.9	194.5	203.5	208.4	

Factor	S.Em(±)	CD (P =0.05)
I	4.63	NS
F	5.35	15.68
I X F	9.26	NS
C.V. (%) :	8.37	

Table 2: Effect of inoculation and nutrient combinations on shoot dry weight (g^{-1}) of maize

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	131.5	161.7	186.6	224.5	176.1
I_2	119.6	144.8	168.0	205.4	159.5
I_3	143.5	183.8	200.7	236.2	191.0
Mean	131.5	163.4	185.1	222.0	

Factor	S.Em(±)	CD (P =0.05)
I	4.58	13.42
F	5.28	15.50
I X F	9.15	NS
C.V. (%) :	9.03	

Table 3: Effect of inoculation and nutrient combinations on number of cob per plant in maize

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	0.70	1.00	1.00	1.13	0.96
I_2	0.68	0.93	1.00	1.07	0.92
I_3	0.80	1.00	1.07	1.33	1.05
Mean	0.73	0.98	1.02	1.18	

Factor	S.Em(±)	CD (P = 0.05)
I	0.03	0.09
F	0.03	0.10
I X F	0.06	NS
C.V. (%) :	10.69	

Table 4: Effect of inoculation and nutrient combinations on number of row per cob in maize

Inoculation	Fertilizer				
	F_0	F_2	F_3	F_4	Mean
I_1	13.0	13.3	13.8	13.9	13.5
I_2	13.0	13.3	13.5	13.5	13.3
I_3	13.1	14.4	14.7	15.1	14.3
Mean	13.0	13.7	14.0	14.1	

Factor	S.Em(±)	CD (P = 0.05)
I	0.36	NS
F	0.42	NS
I X F	0.72	NS
C.V. (%) :	9.14	

Table 5: Effect of inoculation and nutrient combinations on weight (g) per cob in maize

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	78.3	135.3	154.7	166.3	133.7
I_2	70.3	130.6	143.7	157.7	125.6
I_3	91.3	145.2	160.8	172.8	142.5
Mean	80.0	137.0	153.0	165.6	

Factor	S.Em(±)	CD (P = 0.05)
I	3.76	11.02
F	4	.34
I X F	7.51	12.72
C.V. (%) :	9.72	NS

Table 6: Effect of inoculation and nutrient combinations on cob length (cm) in maize

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	13.8	16.6	17.1	18.2	16.4
I_2	12.6	15.3	16.2	18.1	15.5
I_3	14.8	16.9	17.3	18.3	16.8
Mean	13.7	16.3	16.8	18.2	

Factor	S.Em(±)	CD (P = 0.05)
I	0.42	1.23
F	0.48	2.42
I X F	0.84	NS
C.V. (%) :	8.94	

Table 7: Effect of inoculation and nutrient combinations on cob girth (cm) in maize

Inoculation	Fertilizer				
	F_0	F_1	F_2	F_3	Mean
I_1	12.6	13.8	13.9	14.4	13.7
I_2	11.3	13.6	14.0	14.2	13.3
I_3	13.0	14.0	14.2	14.8	14.0
Mean	12.3	13.8	14.1	14.4	

Factor	S.Em(±)	CD (P = 0.05)
I	0.39	NS
F	0.45	1.31
I X F	0.77	NS
C.V. (%) :	9.82	

Table 8: Effect of inoculation and nutrient combinations on 100 seed weight (g) in maize

Inoculation			Fertilizer		
	F_0	F_1	F_2	F_3	Mean
I_1	21.2	24.7	26.5	27.1	24.9
I_2	18.7	23.6	26.2	26.8	23.8
I_3	21.6	25.6	27.0	27.9	25.5
Mean	20.5	24.6	26.6	27.3	

Factor	S.Em(±)	CD (P = 0.05)
I	0.40	NS
F	0.47	1.37
I X F	0.81	NS
C.V. (%) :	5.66	

Table 9: Effect of inoculation and nutrient combinations on grain yield (q ha^{-1}) of maize

Inoculation			Fertilizer		
	F_0	F_1	F_2	F_3	Mean
I_1	7.7	25.0	33.4	38.1	26.1
I_2	7.0	23.7	30.0	36.3	24.3
I_3	10.7	29.5	35.9	43.7	29.9
Mean	8.5	26.1	33.1	39.4	

Factor	S.Em(±)	CD (P = 0.05)
I	0.82	2.40
F	0.97	2.77
I X F	1.63	4.79
C.V. (%) :	10.54	

Table 10: Effect of inoculation and nutrient combinations on stover yield (q ha^{-1}) of maize

Inoculation		Fertilizer			
	F_0	F_1	F_2	F_3	Mean
I_1	26.7	49.6	54.9	60.0	47.8
I_2	24.2	52.9	52.8	58.4	47.1
I_3	33.8	54.9	57.9	64.9	52.9
Mean	28.2	52.4	55.2	61.1	

Factor	S.Em(±)	CD (P = 0.05)
I	1.20	3.62
F	2.23	6.67
I X F	3.40	9.97
C.V. (%) :	10.79	

Table 11: Effect of inoculation and nutrient combinations on stone yield (q ha^{-1}) of maize

Inoculation			Fertilizer		
	F_0	F_1	F_2	F_3	Mean
I_1	4.3	7.7	8.8	9.7	7.6
I_2	3.8	7.9	8.4	9.2	7.3
I_3	5.5	8.4	10.6	12.5	9.2
Mean	4.5	8.0	9.3	10.5	

Factor	S.Em(±)	CD (P = 0.05)
I	0.2	0.6
F	0.2	0.7
I X F	0.4	NS
C.V. (%) :	9.79	

Table 12: Effect of inoculation and nutrient combinations on harvest index (%) in maize

Inoculation			Fertilizer		
	F_0	F_1	F_2	F_3	Mean
I_1	19.92	30.41	34.41	35.34	30.02
I_2	19.98	28.07	32.90	34.93	28.97
I_3	21.42	31.79	34.40	36.08	30.92
Mean	20.44	30.09	33.90	35.45	

Factor	S.Em(±)	CD (P = 0.05)
I	1.80	NS
F	2.67	8.11
I X F	4.18	NS
C.V. (%) :	11.2	

respectively. All these treatment also showed significant superiority over the control. Minimum shoot dry weight 119.6 g^{-1} was recorded in case of without fertilizer with *Azotobacter* inoculated plot (Table 2).

Dual inoculums of AM and *Azotobacter* with different levels of fertilizer significantly show effect on shoot dry weight. The maximum shoot dry weight 236.2 g^{-1} was recorded in treatment requiring 100% recommended dose of fertilizer + AM + *Azotobacter* and followed by 75% (200.7 g^{-1}) and 50% recommended dose of fertilizer (183.8 g^{-1}), respectively. All these treatments also showed significantly superior over the control with mycorrhiza and *Azotobacter* alone (143.5 g^{-1}) (Charantimath and Lakshman, 2007, Mali and Bodhankar, 2009). The interaction effect between dual inoculations with different levels of fertilizer did not show significant variation on shoot dry weight of maize at maturity were reported by Khan and Zaide (2007) and Solanki *et al.* (2011).

Number of cob per plant

Inoculation of *Arbuscular Mycorrhiza* alone with varying doses of fertilizers a positive influence on cob per plant at maturity. The highest number of cob per plant 1.13 were recorded when plot received AM + 100% recommended dose of fertilizer and followed by mycorrhiza inoculation in AM with 75% and 50% RDF, respectively. However, While the all these three treatment superior over *Arbuscular Mycorrhiza* alone with control (0.70 cob per plant) treated plot (Table 3).

Application of different levels of fertilizers with *Azotobacter* show significant variation on number of cob per plant. However, *Azotobacter* with 100% recommended dose of fertilizer application attained maximum cob per plant (1.07), followed by 75% (1.00 cob per plant) and 50% (0.93 cob per plant) RDF with *Azotobacter* inoculation, respectively. Minimum number of cob (0.68 per plant) was observed when plot received zero per cent fertilizer (control) along with *Azotobacter* inoculation.

Similarly, dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose. The maximum number of cob per plant 1.33 was recorded when plot received 100% recommended dose of fertilizer with dual inoculation, followed by 75% (1.07 cob per plant) and 50% (1.00 cob per plant) RDF with dual inoculations, respectively. While, the minimum number of cob per plant 0.80 was recorded were plot received no fertilizer with dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter*. The interaction between dual inoculation and varying levels of fertilizer failed to bring any significant influence on number of cob per plant similar result were also reported by.

Number of row per cob

No marked variation was recorded in number of row per cob as effected by *Arbuscular Mycorrhizal* inoculants and in presence of different levels of fertilizers. The heights number of rows per cob 13.9 recorded where plot received AM with 100% recommended dose of fertilizer and followed by 13.8, 13.3 and 13.0 in plot received 75%, 50% and 0% RDF with *Arbuscular Mycorrhiza* alone, respectively. The minimum number of row per cob was noticed when treatment received zero percent fertilizer with AM inoculation (Table 4).

Similarly, in case of *Azotobacter* inoculation not any variation was recorded on number row per cob of maize crop. However, the maximum number of row per cob 13.5 recorded where plot received *Azotobacter* with 100% recommended dose of fertilizer followed by 13.5 and 13.3 in plot received 75% and 50% RDF with *Azotobacter* alone, respectively. Whereas lowest (13.0 row per cob) was observed with zero per cent fertilizer with *Azotobacter* alone.

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose did not influence on marked variation in number of row per cob of maize. However, the maximum number of row per cob 15.1 recorded where plot received AM + *Azotobacter* with 100% recommended dose of fertilizer and followed by 14.7 and 14.4 where plot received 75%, and 50% recommended dose of fertilizer with AM + *Azotobacter*, respectively. While the minimum number of row per cobs were recorded in plot that received *Arbuscular Mycorrhiza* + *Azotobacter* with control. The number of row per cob decreasing and increasing is may be due to genetic characteristics of the variety. The interaction effect between microbial inoculation and different dose of fertilizer did not show significant influence on number row per cob in maize.

Weight per cob

It is apparent from the data that with inoculation of *Arbuscular Mycorrhiza* has maximum effect on weight of cob in maize, when it was applied with 100% recommended dose of fertilizer. Weight of cob was recorded maximum 166.3 g in case of 100% recommended dose of fertilizer + AM and it was superior over 75% and 50% RDF (154.7 and 135.3 g), respectively. All these treatments also showed significantly superior over the control with *Arbuscular Mycorrhiza* alone (78.3 g). The application of microbial inoculants with chemical fertilizer may act as source and supply of essential plant nutrients in maize that's why cob weight increases (Table 5).

Use of *Azotobacter* inoculation helped the test plant to attain higher cob weight (125.6 g) in presence of fertilizer application each plants had on average more weight of cob its value was highest when *Azotobacter* was applied with 100% recommended dose of fertilizer (157.7 g cob), followed by 75% (143.7 g cob) and 50% RDF (130.6 g cob), respectively. The minimum cob weight (70.3 g) was registered when plot received *Azotobacter* inoculation with no fertilizer treatment.

Dual inoculum of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer application shows the significant improvement on weight of cob. The maximum cob weight 172.8 g was recorded in presence of 100% recommended dose of fertilizer + AM + *Azotobacter* and followed by 75% (160.8 g cob) and 50% RDF (145.2 g cob), respectively. All these treatment also showed significantly superior over the control with *Azotobacter* alone. Lowest weight of cob (91.3 g) noticed when treatment received *Azotobacter* inoculation with no fertilizer application. The interaction effect between inoculation and different dose of fertilizer failed to show significant influence on weight of cob with maize cultivar similar result were also reported by Solanki *et al.* (2011).

Cob length

Inoculation of *Arbuscular Mycorrhiza* alone with different doses of fertilizer a positive influence was noticed on cob length in maize after harvesting. The maximum cob length

18.2 cm recorded where treatment received with AM + 100% recommended dose of fertilizer and followed by *Arbuscular Mycorrhiza* with 75% (17.1 cm) and 50% RDF (16.6 cm), respectively. However, the lowest cob length 13.8 cm in soils which received only AM (Table 6).

Application of varying levels of fertilizer with *Azotobacter* incorporation shows the significant variation on cob length of maize. However, *Azotobacter* with 100% recommended dose of fertilizer application attained maximum length of cob (18.1 cm), followed by 16.2 cm with 75% and 15.3 cm with 50% recommended dose of fertilizer, respectively. Whereas the lowest (12.6 cm) was observed with *Azotobacter* alone without fertilizer.

Similarly, dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose significant increasing the cob length of maize. The maximum cob length 18.3 cm was recorded when plot received 100% recommended dose of fertilizer with dual inoculation. It was followed by in soil supplemented with 75% (17.3 cm) and 50% RDF (16.9 cm), respectively. While minimum cob length 14.8 cm was recorded in plot that received no fertilizer with dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* treatments. The interaction effect between microbial inoculation and various doses of fertilizer did not show any significant influence on cob length of maize similar result were also reported by Solanki *et al.* (2011).

Cob girth

Maize crop raised during *rabi* 2015-16 did not produce significant effect on cob girth as effected by AM inoculants and in presence of different levels of fertilizer. The heights cob girth 14.4 cm recorded where plot received *Arbuscular Mycorrhiza* with 100% recommended dose of NPK and followed by 13.9 and 13.8 cm in plot received 75% and 50% RDF, respectively. The least cob girth, 12.6 cm was observed when mycorrhiza alone was applied (Table 7).

Application of *Azotobacter* inoculation with different dose of plant nutrient did not show any variation was recorded on cob girth in maize crop. However, the maximum cob girth 14.2 cm recorded where plot received *Azotobacter* with 100% recommended dose of fertilizer. The mean cob girth13.3 cm was recorded in soil which received plant nutrient with *Azotobacter* inoculation. Treatment received 75% recommended dose of fertilizer with microbial inoculation were registered 14.0 cm cob girth followed by 50% RDF + *Azotobacter* (13.6 cm).

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose did not have significant influence on cob girth of maize. However, the maximum cob girth 14.8 cm was recorded where plot received AM + *Azotobacter* with 100% recommended dose of fertilizer and followed by 14.2 and 14.0 cm in plot which received 75%, and 50% RDF with Mycorrhiza + *Azotobacter* inoculation, respectively. While the lowest 13.0 cm cobs girth was recorded in plot that received *Arbuscular Mycorrhiza* + *Azotobacter* with control (no fertilizer). Application of different doses of fertilizer (0, 50, 75 and 100% RDF) significantly influenced the mean cob girth of maize and varies from 12.3 to 14.4 cm, respectively. The interaction effect between inoculation and varying fertilizer doses failed to show any significant change on cob girth of maize similar finding were also reported by Solanki et *al.* (2011).

100 seed weight

No marked variation was recorded in 100 seed weight of maize as affected by *Arbuscular Mycorrhiza* inoculants in presence of different levels of fertilizer. The maximum 27.1 g seed weight was recorded when the plot received AM with 100% recommended dose of fertilizer and it is closely followed by 26.5 and 24.7 g in plot that received 75% and 50% RDF, respectively. Minimum 100 seed weight 21.2 g recorded with treatment received no fertilizer + AM. No any significant variation was recorded on 100 seed weight in maize crop (Table 8).

Similarly, in case of *Azotobacter* inoculation no significant variation was recorded on 100 seed weight of maize. However, the highest 100 seed weight 26.8 g was recorded where plot received *Azotobacter* inoculation with 100% recommended dose of fertilizer and followed by 26.2, 23.6 and 18.7 g in treatment received 75% and 50% recommended dose of fertilizer and control, respectively.

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer failed to show any influence on 100 seed weight of maize. However, the maximum 100 seed weight 27.9 g was recorded where plot received AM + *Azotobacter* with 100% recommended dose of fertilizer and followed by 27.0 and 25.6 g in plot received 75%, and 50% RDF with AM + *Azotobacter*, respectively. While the lowest (21.6 g) 100 seed weight was recorded in plot that received AM and *Azotobacter* with no fertilizer application treated plot. The interaction effect between inoculation and varying fertilizer dose did not show significant influence in 100 seed weight of maize crop were also reported by Seyedlar *et al.* (2014).

Grain yield

It is apparent from the data given in that *Arbuscular Mycorrhiza* showed positive effect on grain yield when it was applied with 100% recommended dose of fertilizer (38.1 q ha^{-1}) followed by 75% (33.4 q ha^{-1}) and 50% (25.0 q ha^{-1}) recommended dose of fertilizer, respectively, and it showed minimum effect on grain yield when it was applied with without any dose of fertilizer (7.7 q ha^{-1}). Application of AM with 100, 75 and 50% recommended dose of fertilizer showed significantly superior over no fertilizer (control) with *Arbuscular Mycorrhiza* alone (Table 9).

Grain yield of maize responded positively with increasing dose of fertilizer along with *Azotobacter*. Grain yield attained maximum value when *Azotobacter* was applied with 100% recommended dose of fertilizer (36.3 q ha^{-1}) followed by 75% (30.0 q ha^{-1}) and 50% (23.7 q ha^{-1}), respectively. However, minimum grain yield was recorded when *Azotobacter* applied with control (7.0 q ha^{-1}). It clearly showed the application of *Azotobacter* with 100, 75 and 50% recommended dose of fertilizer significantly superior over *Azotobacter* alone and with control (without fertilizer) similar result were also reported by Soleimanzadeh and Gooshchi (2013).

An appraisal of data is given in Table 9, the maximum grain yield 43.7 q ha^{-1} was recorded when dual inoculums applied with 100% recommended dose of fertilizer followed by 75% (35.9 q ha^{-1}) and 50% (29.5 q ha^{-1}) recommended dose of fertilizer respectively. While the minimum amount grain yields (10.7 q ha^{-1}) was recorded in control with dual inoculation. It is clearly indicated that the application of AM and *Azotobacter* with 100, 75 and 50% RDF were significantly superior over the *Arbuscular Mycorrhiza* alone with no fertilizer treated plot. The interaction effect between inoculation and varying dose of fertilizer did show significant influence on grain yield of maize. The most efficient interaction resulted from the plants raised with microbial inoculation (Mycorrhiza and *Azotobacter*) applied with 100, 75 and 50% recommended dose of fertilizer with a yield of 39.4, 33.1 and 26.1 q ha^{-1}, respectively similar result were also reported by Khan and Zaide (2007), Mirzakhani *et al.* (2009), Bahrani *et al.* (2010), Solanki *et al.* (2011), Sarajuoghi *et al.* (2012) and Seyedlar *et al.* (2014).

Stover yield

Application of *Arbuscular Mycorrhiza* with different doses of fertilizer influenced the stover yield significantly. The stover yield exhibited and increased trends as recommended dose of fertilizer was increased. Stover yield attained highest value when *Arbuscular Mycorrhiza* applied with 100% RDF (60.0 q ha^{-1}) followed by 75% (54.9 q ha^{-1}) and 50% RDF (49.6 q ha^{-1}), respectively. However, minimum stover yield was recorded when AM was applied with control (26.7 q ha^{-1}). It is clearly showed that the application of AM with 100, 75 and 50% recommended dose of fertilizer is significantly superior over the *Arbuscular Mycorrhiza* alone with control (Table 10).

It is apparent from the data given in the Table 10 that *Azotobacter* showed positive effect on stover yield 58.4 q ha^{-1} when it was applied with the 100% recommended dose of fertilizer followed by 75% (52.8 q ha^{-1}) and 50% (52.9 q ha^{-1}) recommended dose of fertilizer, respectively, and it showed minimum effect on stover yield when it was applied with no fertilizer (24.2 q ha^{-1}). Application of *Azotobacter* with 100, 75 and 50% RDF showed significantly superior over control with *Azotobacter* alone similar result was also reported by Soleimanzadeh and Gooshchi (2013).

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer gave significant impact on stover yield which is presented in Table 10. The maximum stover yield 64.9 q ha^{-1} was recorded when dual inoculums applied with 100% recommended dose of fertilizer followed by 75% (57.9 q ha^{-1}) and 50% RDF (54.9 q ha^{-1}), respectively. While the minimum amount stover yields (33.8 q ha^{-1}) was recorded in control with dual inoculation treated plot. It is clearly indicated that the application of *Arbuscular Mycorrhiza* and *Azotobacter* with 100, 75 and 50% RDF was significantly superior over the AM alone with control. Application of microbial inoculants along with fertilizer and in dual inoculation tune of stover yield to the tune of mean yield 47.1 to 52.9 q ha^{-1}, based on the statistical analysis it was found that inoculation helped the plant to gain in more stover yield over control (no fertilizer). The interaction effect between I X F of inoculation and different dose of fertilizer did show positive and significant influence on stover yield of maize. The best influence was recorded with 100% recommended dose of fertilizer with dual inoculation (Mycorrhiza and *Azotobacter*) yielded 60.0 and 64.9 q ha^{-1} stover yield with AM and combined inoculation, respectively, and being statistically superior over respective control and others similar result were also reported by, Bahrani *et al.* (2010), Solanki *et al.* (2011), Sarajuoghi *et al.* (2012) and Seyedlar *et al.* (2014).

Stone yield

Inoculation of *Arbuscular Mycorrhiza* alone with varying doses of fertilizers showed a positive influence on stone yield of maize after harvesting. The maximum stone yield 9.7 q ha^{-1} was recorded when plot received AM + 100% recommended dose of fertilizer and followed by 8.8 and 7.7 q ha^{-1} in AM with 75% and 50% RDF, respectively (Table 11). However, all these three treatments were superior over only *Arbuscular Mycorrhiza* treated plot without fertilizer (4.3 q ha^{-1}).

Application of varying levels of fertilizers with *Azotobacter* incorporation did show significant variation on stone yield of maize. However, *Azotobacter* with 100% recommended dose of fertilizer application attained maximum stone yield (9.2 q ha^{-1}), followed by 75% (8.4 q ha^{-1}) and 50% (7.9 q ha^{-1}) recommended dose of fertilizer with *Azotobacter*, respectively. While all these three treatments showed superiority over AM alone with control (3.8 q ha^{-1}).

Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer showed positively effect on stone yield of maize. The maximum stone yield 12.5 q ha^{-1} were recorded when plot received 100% recommended dose of fertilizer with dual inoculation, followed by 75% (10.6 q ha^{-1}) and 50% (8.4 q ha^{-1}) recommended dose of fertilizer, respectively. While minimum stone yield 5.5 q ha^{-1} was recorded in plot that received control with dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter*. The interaction effect between inoculation and different dose of fertilizer did not show any significant effect on stone yield in maize similar finding were also reported by Sarajuoghi *et al.* (2012) and Seyedlar *et al.* (2014).

Harvest index (HI)

No marked variation recorded in harvest index in maize as affected by *Arbuscular Mycorrhiza* inoculants and in presence of different level of fertilizers. However, the maximum 35.34% was noticed when the plot received AM with 100% recommended dose of fertilizer and followed by 34.41%, 30.41% and 19.92% in plot that received 75%, 50% and control (no fertilizer) with *Arbuscular Mycorrhiza* inoculation, respectively (Table 12).

No change in harvest index (HI) of maize was noticed. However, the maximum harvest index 34.93% recorded were plot received *Azotobacter* with 100% recommended dose of fertilizer and followed by 32.90%, 28.07% and 19.98% in plot received 75%, 50% RDF and control with *Azotobacter* inoculation, respectively.

Harvest index failed to bring any significant effect due to various microbial inoculations. Dual inoculation of *Arbuscular Mycorrhiza* and *Azotobacter* with different levels of fertilizer dose did not influence on marked variation in harvest index of maize. However, the maximum harvest index 36.08% recorded was plot received AM + *Azotobacter* with 100% recommended dose of fertilizer and followed by 34.40% and 31.79% in plot received 75%, and 50% RDF with AM + *Azotobacter*, respectively. While the lowest (21.42%) harvest index was recorded in plot received AM + *Azotobacter* with control (Table 12). The interaction effect between microbial inoculation and different doses of fertilizer failed to bring any significant changes on harvest index of maize These results are in close conformity with the findings of Bahrani *et al.* (2010), Solanki *et al.* (2011) and Seyedlas *et al.* (2014).

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