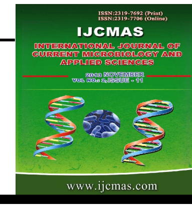

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 2 Number 11 (2013) pp. 96-104**
http://www.ijcmas.com

Original Research Article

Effect of endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on the maximization of growth and yield of maize (*Zea mays* L.)

R.Sivakamasundari* and G. Usharani

Department of Microbiology, Annamalai University, Chidambaram-608 002, Tamil Nadu, India
Corresponding author

A B S T R A C T

Maize is grown in almost all the states of India. The crop occupies an area of 6.11 million hectares with a production of 9.12 million tonnes during the period of 2012 - 2013 in India. Endophytic bacteria have the ability to promote growth and inhibit plant disease, and as they are in intimate contact with the plant they are an attractive choice as plant growth promoters and biological control agents. Arbuscular mycorrhizal (AM) fungi are worldwide distributed soil fungi, forming symbiosis with most plant families. Their importance in natural and semi natural ecosystems is commonly accepted and materialized by improved plant productivity and diversity as well as increased plant resistance against biotic and abiotic stresses. In the present study, effect of endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on the growth and yield of maize was investigated. Maximum germination percentage, vigour index, plant height, dry matter production, yield and yield attributes were recorded observed in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P). Minimum growth and yield parameters were recorded in the treatment T_3 (*Glomus fasciculatum* alone).

Keywords

Maize; Growth parameters; Yield parameters; Endophytic *Pseudomonas fluorescens; Glomus fasciculatum*.

Introduction

Maize is an important cereal crop of India, stands 3rd in area and production after rice and wheat. Currently it is cultivated over an area of 8.49 m. ha with a production of 21.28 million tonnes. The productivity in India is much lower (2.51 t ha^{-1}) than world average productivity of 4.34 t ha^{-1}. In Tamil Nadu, maize is grown over an area of 1.2 m. ha with a production of 3.6 million tonnes and productivity of 3.0 t ha^{-1}. Being an exhaustive crop, it has very high nutrient requirement and its productivity depends closely on nutrient management. During the last ten years, the area under maize in Tamil Nadu has increased by 41 per cent (Sharma and Gupta, 2013).

Plants are generally associated with

diverse microorganisms. Endophytic organisms are those that colonize the plant internal tissue showing no external sign of infection or negative effect on their host (Schulz and Boyle, 2006). Endophytic bacteria have been isolated from a large diversity of plants. Microorganisms like *Bacillus, Enterobacter, Klebsiella, Pseudomonas, Burkholderia, Pantoea, Agrobacterium* and *Methylobacterium* sp. constitute the endophytes commonly isolated from diverse plants such as rice, wheat, maize, cotton, clover, potato, sugarcane, tomato, cucumber and wild grasses (Bacon and Hinton, 2006). Only a few of these plants have ever been completely studied relative to their endophytic biology. Consequently, the opportunity to find new and beneficial endophytic microorganisms among the diversity of plants in different ecosystems is considerable.

The endophytic bacteria have a multitude of applications that enhance agricultural production; they enhance wheat growth through production of phytohormones, increase rice production by increasing mineral availability, increase cotton disease resistance, contribute to corn pest management, fix nitrogen in rice and wheat, decrease susceptibility to frost damage, and increase potato tuber formation under heat stress conditions.

Lack of host specificity is even more characteristic of this symbiosis than other types known. Studies on Arbuscular mycorrhizal fungi conducted during last few decades envisaged their occurrence in a wide variety of hosts, different habitats and variability in quality and quantity (Jalaluddin, 2005). Arbuscular mycorrhizal fungi are geographically ubiquitous. They are commonly found in association with agricultural crops, shrubs, tropical tree species and some temperate trees. Their nutritional requirements are not specific. Arbuscular mycorrhizal associations are formed by non septate Zygomycetes and Phycomycetes fungi. Some examples of Arbuscular mycorrhizal fungi are *Glomus*, *Gigaspora*, *Acaulospora*, *Entrophospora* and *Scutellospora* of which *Glomus* is the most common fungus (Sureshkumar Singh *et al*., 2003; James *et al*., 2008).

Materials and Methods

The field experiments were conducted in the farmer's field, Vadalur, Tamil Nadu, India (11º24'N and 71º41'E) from 2012 - 2013. The relative humidity was in the range of 96 to 78 percent with the mean of 89 per cent. The experimental soil is deep fairly drained clay with Organic matter (0.65%), pH (7.2) and EC (0.56 m mhos/cm). The field experiments were conducted on Maize **(**Co - 1**)** during 2012 - 2013. The experiments comprised of seven treatments *viz*., T_1 – Control (100% P), T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone, T_3 – *Glomus fasciculatum* alone, T_4 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) + *Glomus fasciculatum*, T_5 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) + 75% P, T_6 – *Glomus fasciculatum* + 75% P and T_7 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) + *Glomus fasciculatum* + 75% P. Experiments were conducted in Randomized block design (RBD) with three replications. The experimental field was well ploughed, beds were dibbled in lines at 60 × 20 cm. Observation on germination percentage, vigour index, plant height, dry matter production, yield and yield attributes were recorded. Five plants from each treatment were randomly selected for recording growth parameters periodically at 30 and 60 days after sowing (DAS) and at harvest.

Results and Discussion

Maize is grown in almost all the states of India. The crop occupies an area of 6.11 million hectares with a production of 9.12 million tonnes during the period of 2012 - 2013 in India. In Tamil Nadu, it is cultivated over an area of 29,300 hectares with a production of 46,500 tonnes during the period of 2012 - 2013. Maize grain contains about 10% protein, 4% oil, 70% carbohydrates, 23% crude fibre, 10.4% albuminoides, 1.4% ash. A maize grain has significant quantities of vitamin - A, nicotinic acid, Riboflavin and vitamin - E. Maize crop is utilized in many ways like other grain crops. Over 85% of maize produced in the country is consumed as human food (Rautaray *et al*., 2013; Lee *et al*., 2013; Tiwari *et al*., 2013).

Endophytic bacteria have the ability to promote growth and inhibit plant disease, and as they are in intimate contact with the plant they are an attractive choice as plant growth promoters and biological control agents. Selection for competitive ability is an area in which there has been little research to date, and the challenge is to encourage the establishment of beneficial bacterial communities within the host plant, early in the crop's development or by artificially introducing specific genetic components that confer some long lasting benefit. Endophytic *Pseudomonas fluorescens* produce highly potent broad spectrum antifungal molecules against various phytopathogens, thus acting as effective biocontrol agents (Garcia *et al*., 2001). They are well equipped as primary root colonizers. Through, several mechanisms *viz*., production of antibiotics (Gutterson *et al*., 1988), siderophores (Kloepper *et al*., 1980), HCN (Defago *et al*., 1990) and competition for space and nutrients (Elad *et al*., 1987), they inhibit soil borne plant pathogens. They could serve as promising bioinoculants for agricultural system to increase productivity since the action of such bacteria is highly specific, ecofriendly and cost - effective.

In the present study, effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Germination percentage and Vigour index of Maize was investigated and the results were furnished in Table - 1. Maximum Germination percentage (94.05%) and Vigour index (2191.87) was observed in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Germination percentage - 93.90% and Vigour index - 2125.40). Minimum Germination percentage (84.20%) and Vigour index (1380.96) was observed in the treatment T_3 (*Glomus fasciculatum* alone).

The effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on plant height of Maize was measured in the present research. The observations recorded on plant height at 30 DAS, 60 DAS and at harvest are presented in Table – 2. Maximum plant height was recorded during the harvest and highest plant height (177.21 cm) was recorded in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Plant height – 176.80 cm). Lowest plant height (134.31 cm) was observed in the treatment T_3 (*Glomus fasciculatum* alone).

Kumar *et al.* (1999) reported a significant increase in maize plant height by inoculation of different bacterial strains in combination with *Glomus fasciculatum*. Similar results that plant height increases with *Glomus fasciculatum* and *Pseudomonas fluorescens* were reported by Maqsood *et al.* (2001), Ayub *et al*. (2002) and Sharar *et al*. (2003). Burd *et al*. (2000) reported that plant growth promoting rhizobacteria might enhance plant height and productivity by synthesizing phytohormones, increasing the local availability of nutrients, facilitating the uptake of nutrients by the plants decreasing heavy metal toxicity in the plants antagonizing plant pathogens.

In the present investigation, the effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Dry matter production was investigated. The observations recorded on dry matter production at 30 DAS, 60 DAS and at harvest are presented in Table – 3. Maximum dry matter production was recorded during the harvest and more dry matter production (260.34 t ha^{-1}) was recorded in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Dry matter production – 259.88 t ha^{-1}). Less dry matter production (196.23 t ha^{-1}) was observed in the treatment T_3 (*Glomus fasciculatum* alone). Tomar (1998) reported that endophytic bacterial siaolates along with rock phosphate fertilization significantly increased dry matter yield of maize plants. The effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Number of grains per cob and Number of grains per row in Maize and the results were presented in Table - 4. Maximum number of grains per cob (480.67) and number of grains per row (31.33) was noticed in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Number of grains per cob - 480.05 and Number of grains per row - 30.93). Minimum Number of grains per cob (432.80) and Number of grains per row (15.10) was observed in the treatment T_3 (*Glomus fasciculatum* alone).

In the present research, effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Length of cob, Girth of cob and Filled to unfilled ratio in Maize was studied and the results were showed in Table - 5. Maximum length of cob (17.43 cm), Girth of cob (17.65 cm) and Filled to unfilled ratio (25:1) was recorded in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Length of cob – 17.15 cm, Girth of cob – 17.25 cm and Filled to unfilled ratio – 24:1). Minimum length of cob (11.90 cm), Girth of cob (12.35 cm) and Filled to unfilled ratio (12:1) was observed in the treatment T_3 (*Glomus fasciculatum* alone).

These results are in line with the findings of Khan *et al*. (1999) reported significant effect of bacteria and AM fungal application applications on number of cobs per plant. Kumar *et al*. (1999) who reported significant increase in number of plants per meter row length by inoculation of *Azotobacter chroococcum.* The results of the present research are also in agreement with those of Maqsood *et al*. (2001), Ali *et al*. (2002), Younas (2002), Sharar *et al*. (2003), Rasheed *et al*. (2004) and Oktem *et al*. (2005) who reported that number of grains rows per cob, grain

Table.1 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Germination percentage and Vigour index of Maize

Treatments	**Germination percentage (%)**	**Vigour index**
T_1 – Control (100% P)	93.90	2125.40
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	86.88	1420.75
T_3 – *Glomus fasciculatum* (GF - 5) alone	84.20	1380.96
T_4 - EPFR – 4 + GF – 5	91.38	2075.50
T_5 - EPFR – 4 + 75% P	90.95	1890.25
T_6 – GF - 5 + 75% P	88.25	1670.92
T_7 - EPFR – 4 + GF – 5 + 75% P	94.05	2191.87
SE_D		
CD (P = 0.05)		

Table.2 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Plant height of Maize

Treatments	**Plant height (cm)**		
	30 DAS	**60 DAS**	**Harvest**
T_1 – Control (100% P)	75.78	126.94	176.80
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	60.35	90.35	142.30
T_3 – *Glomus fasciculatum* (GF - 5) alone	56.00	83.13	134.31
T_4 - EPFR – 4 + GF – 5	72.18	117.30	166.90
T_5 - EPFR – 4 + 75% P	68.45	110.15	159.70
T_6 – GF - 5 + 75% P	63.30	102.50	150.46
T_7 - EPFR – 4 + GF – 5 + 75% P	76.45	127.12	177.21
SE_D			
CD (P = 0.05)			

Table.3 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Dry matter production in Maize

Treatments	**Dry matter production (t ha^{-1})**		
	30 DAS	**60 DAS**	**Harvest**
T_1 – Control (100% P)	36.05	114.75	259.88
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	27.90	106.62	210.85
T_3 – *Glomus fasciculatum* (GF - 5) alone	25.12	95.34	196.23
T_4 - EPFR – 4 + GF – 5	34.12	112.30	242.15
T_5 - EPFR – 4 + 75% P	32.40	110.80	230.20
T_6 – GF - 5 + 75% P	30.80	107.75	223.80
T_7 - EPFR – 4 + GF – 5 + 75% P	36.70	115.08	260.34
SE_D			
CD (P = 0.05)			

Table.4 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on number of grains per cob and number of grains per row in Maize

Treatments	Number of grains cob^{-1}	Number of grains row^{-1}
T_1 – Control (100% P)	480.05	30.93
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	445.70	18.00
T_3 – *Glomus fasciculatum* (GF - 5) alone	432.80	15.10
T_4 - EPFR – 4 + GF – 5	472.18	27.30
T_5 - EPFR – 4 + 75% P	465.20	25.75
T_6 – GF - 5 + 75% P	458.25	22.48
T_7 - EPFR – 4 + GF – 5 + 75% P	480.67	31.33
SE_D		
CD (P = 0.05)		

Table.5 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Length of cob, Girth of cob and Filled to unfilled ratio in Maize

Treatments	Length of cob (cm)	Girth of cob (cm)	Filled to unfilled ratio
T_1 – Control (100% P)	17.15	17.25	24:1
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	12.70	13.10	14:1
T_3 – *Glomus fasciculatum* (GF - 5) alone	11.90	12.35	12:1
T_4 - EPFR – 4 + GF – 5	16.66	16.80	22:1
T_5 - EPFR – 4 + 75% P	15.80	16.02	20:1
T_6 – GF - 5 + 75% P	14.20	14.92	17:1
T_7 - EPFR – 4 + GF – 5 + 75% P	17.43	17.65	25:1
SE_D			
CD (P = 0.05)			

Table.6 Effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Grain weight per plant, Cob weight per plant and 100 seed weight in Maize

Treatments	Grain weight plant^{-1} (g)	Cob weight plant^{-1} (g)	100 seed weight (g)
T_1 – Control (100% P)	144.95	276.37	27.15
T_2 – Endophytic *Pseudomonas fluorescens* (EPFR – 4) alone	118.44	258.85	23.70
T_3 – *Glomus fasciculatum* (GF - 5) alone	107.61	245.36	22.18
T_4 - EPFR – 4 + GF – 5	140.20	274.10	26.75
T_5 - EPFR – 4 + 75% P	132.55	271.35	25.50
T_6 – GF - 5 + 75% P	124.90	267.60	24.48
T_7 - EPFR – 4 + GF – 5 + 75% P	145.36	276.88	27.62
SE_D			
CD (P = 0.05)			

weight per cob and 1000 grain weight was increased with application of fertilizers in combination with bioinoculants. The findings of Capuno *et al.* (1980) are almost similar to the present study who found that biofertilizers increased the 1000 grain weight of sorghum and maize.

The effect of Endophytic *Pseudomonas fluorescens* and *Glomus fasciculatum* on Grain weight per plant, Cob weight per plant and 100 seed weight in Maize was estimated in the present research and the results were given in Table – 6. Maximum Grain weight per plant (145.36 g), Cob weight per plant (276.88 g) and 100 seed weight (27.62 g) was recorded in the treatment T_7 (Endophytic *Pseudomonas fluorescen* + *Glomus fasciculatum* + 75% P). The treatment T_7 was on par with the treatment T_1 (Control - 100% P) (Grain weight per plant – 144.95 g, Cob weight per plant – 276.37 g and 100 seed weight – 27.15 g). Minimum Grain weight per plant (107.61 g), Cob weight per plant (245.36 g) and 100 seed weight (22.18 g) was observed in the treatment T_3 (*Glomus fasciculatum* alone). Saad and Hammad (1998) also reported that the greatest grain yield of maize was found with inoculation of bacteria and application of AM fungi. Similar results were reported by Maqsood *et al*. (2001), Ali *et al*. (2002), Younas (2002), Sharar *et al*. (2003), Rasheed *et al*. (2004) and Oktem *et al*. (2005) who reported the increase in grain yield and stalk yield with application of bacterial isolates in combination with AM fungal isolates.

Kundu and Gaur (1984) reported that the grain and stalk yields of maize (*Zea mays* L.) increased significantly due to inoculations. They further reported that the phosphate solubilizing microorganisms improved phosphorus uptake over control with and without chemical fertilizers. Tomar *et al*. (1998) applied different combinations of *Azotobacter*, *Azospirillum*, Arbuscular mycorrhizae, *Pseudomonas fluorescens* and NPK fertilizers in maize (*Zea mays* L.). They reported that yield was 2.63 tones ha^{-1} in control, 3.41 tones ha^{-1} with NPK only and the highest (3.80 tones ha^{-1}) with NPK + AM + PSB. The results obtained in the present study were in line with the findings of Tomar *et al*. (1998).

Saad and Hammad (1998) also reported that the highest stalk yield was obtained with inoculation of *Pseudomonas fluorescens* and application of AM fungi. The results are also in line with Kumar *et al.* (1999), Chabot and Antoun (1996) and Kundu and Gaur (1984) who also reported increase in biological yield of sorghum, maize and rice respectively. On the basis of this study, it was concluded that the endophytic *Pseudomonas fluorescens* in combination with AM fungi *Glomus fasciculatum* and 75% NPK significantly improved the growth, yield parameters and biochemical constituents in Maize.

References

Ali, J., J. Bakht, M. Shafi, S. Khan and W. A. Shah. 2002. Uptake of nitrogen as affected by various combinations of nitrogen and phosphorus. Asian J. PI. Sci., 1: 367 - 369.

Ayub, M., M. A. Nadeem, M. S. Sharar and N. Mahmood. 2002. Response of maize (Zea *mays* L.) fodder to different levels of nitrogen and phosphorus. *Asian* J. Pl. Sci:, 9: 352 – 354.

Bacon, C.W. and D. M. Hinton. 2006. Bacterial endophytes: the endophytic niche, its occupants and its utility. *In*: Gnanamanickam, S.S. (ed) Plant associated bacteria. Springer, New

Delhi, pp 155 – 194.

Burd, G. I., D. G. Dixon and B. R. Glick. 2000. Plant growth promoting rhizobacteria that decrease heavy metal toxicity in plants. Can. J. Microbiol., 33: 237 - 245.

Capuno, R.B., B.E. Faber and R.G. Eacalada. 1980. Growth and yield of sorghum and maize as influenced by green manure and soil organic matter content. *Ann*. Trop. Res., 2: 105 – 110.

Chabot, R. and H. Antoun, 1996. Growth promotion of maize and lettuce by phosphate solubilizing *Rhizobium leguminosarum.* Pl. Soil, 184: 311 – 321.

Defago, G., C. H. Berling, U. Borger, C. Keel and C. Voisard. 1990. Suppression of black rot of tobacco by a *Pseudomonas* strain: Potential applications and mechanisms, In: Biological Control of Soil Borne Plant Pathogen, (*Eds*) Horn by, D., Cook, R.J. and Henis, Y., CAB International, 93 - 108.

Elad, Y., I. Chet and R. Bakker. 1987. Increased growth response of plants induced by Rhizobacteria antagonistic to soil borne pathogenic fungi. *Plant and Soil,* 98: 325- 330.

Garcia, D. S. I. E., R. K. Hynse and L. M. Nelson. 2001. Cytokinin production by plant growth promoting rhizobacteria and selected mutants. Canadian. J. Microbiol. 47: 404 - 411.

Gutterson, N., J. S. Ziegle and G. J. Warren. 1988. Genetic determinants for catabolic induction of antibiotic biosynthesis in *Pseudomonas fluorescens* HV37a. J. Bacteriol. 170: 380 - 385.

Jalaluddin, M. 2005. Effect of inoculation with VAM - fungi and *Bradyrhizobium* on growth and yield of soybean in Sindh. Pak. J. Bot., 37(1): 169 - 173.

James, B., U. Kung, D. Rodel, U. Lasco, Lorettu, N. Dela Cruz, E. Reynaldo, Dela Cruz and Tariq Husain. 2008. Effect of Vesicular Arbuscular Mycorrhiza (VAM) fungi Inoculation on coppicing ability and drought resistance of *Senna spectabilis.* Pak. J. Bot., 40(5): 2217 – 2222.

Khan, M. A., N. U. Khan, K. Ahmad, M. S. Baloch and M. Sadiq. 1999. Yield of maize hybrid-3335 as affected by NP levels. Pakistan. J. Biol. Sci., 2: 857 – 859.

Kloepper, J. W., J. Leong, M. Teintze and M. N. Schroth. 1980. *Pseudomonas* siderophores: A mechanism explaining disease suppressive soils. Current Microbiol. 4: 317 - 320.

Kumar, V., S. S. Punia, K. Lakshminarayana and N. Narula, 1999. Effect of phosphate solubilizing analogue resistant mutants of *Pseudomonas fluorescens* on maize. Indian J. Agric. Sci., 69: 198 – 200.

Kundu, B. S and A. C. Gaur, 1984. Maize response to inoculation with N_2 fixing and P – solubilizing microorganisms. Pl. Soil, 79: 227 – 234.

Lee, H., H.S. Ha, C.S. Lee, Y.B. Lee and P.J. Kim, 2013. Fly ash effect on improving soil properties and rice productivity in Korean paddy soil. Bioresour. Technol., 97: 1490 - 1497.

Maqsood, M., A. M. Abid, A. Iqbal and M. I. Hussain. 2001. Effect of variable rate of nitrogen and phosphorus on growth and yield of maize (golden). Online J. Biol. Sci., 1: 19 - 20.

Oktem, A. G and A. Oktem. 2005. Effect of nitrogen and intra spaces on sweet corn characteristics. Asian J. Plant Sci., 4: 361 - 364.

Rasheed, M., W. M. Bhutta, M. Anwar - ul – Haq and A. Ghaffar. 2004. Genotypic response of maize hybrids to NP applications Intl. J. Agric., Biol., 4: 721-722.

Rautaray, S.K., B.C. Ghosh and B.N. Mittra, 2013. Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice - mustard cropping sequence under acid lateritic soils. Bioresour. Technol., 90: 275 - 283.

Saad, O. A. O and A.M.M. Hammad. 1998. Fertilizing wheat plants with rock phosphate combined with phosphate dissolving bacteria and V.A– mycorrhizae as alternate for ca – superphosphate. Annals Agric. Sci. Cairo, 43: 445 – 460.

Schulz, B and C. Boyle. 2006. What are endophytes? *In*: Schulz, B.J.E., Boyle, C.J.C. and Sieber, T.N., (eds.) Microbial Root Endophytes, Springer-Verlag, Berlin, pp.1 – 13.

Sharar, M. S., M. Ayub, M. A. Nadeem and N Ahmad. 2003. Effect of different rates of nitrogen and phosphorus on growth and grain yield of maize. Asian Plant Sci., 2(3): 347 - 349.

Sharma, M. P and J. P. Gupta. 2013. Effect of organic materials on grain yield and soil properties in maize-wheat cropping system. Indian J. Agric. Sci., 68: 715 - 717.

Sureshkumar Singh, S.C. Tiwar and M.S. Dkhar. 2003. Species diversity of vesicular-arbuscular mycorrhizal (VAM) fungi in jhum fallow and natural forest soils of Arunachal Pradesh, north eastern India. Tropical Ecology, 44(2): 207 - 215.

Tiwari, S., B. Kumari and S. N. Singh, 2013. Evaluation of metal mobility/immobility in fly ash induced by bacterial strains isolated from the rhizospheric zone of *Typha latifolia* growing on fly ash dumps. Bioresour. Technol., 99: 1305-1310.

Tomar, U.S., I.S. Tomar and A.K. Badaya, 1998. Response of chemical and biofertilizer on some matric traits in maize. Crop Res. Hissar. New Delhi. 16: 408 – 10

Younas, M. H., Rehman and G. Hayder. 2002. Magnitude of variability for yield and associated traits in maize hybrids. Asian J. Plant Sci., 1(6): 694 - 696.