The Bioscan 11(1): 331-334, 2016 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EFFECT OF BIOINOCULANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD (*TAGETES ERECTA* L.) CV. PUSA NARANGI GAINDA

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KEYWORDS
Bioinoculants
Azotobacter
Phosphate Solubilizing Bacteria (PSB)

Received on :
08.12.2015

Accepted on :
18.02.2016

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ABSTRACT
To study the effect of bioinoculants on growth and yield of African marigold (*Tagetes erecta* L.) cv. 'Pusa Narangi Gainda' an experiment was carried out with sixteen treatment combinations, consisting two levels of nitrogen *i.e.* full N (200 kg N/ha) and 3/4thN (150 Kg/ha) and two levels of Phosphorus *i.e.* full P_2O_5 (60 kg P_2O_5/ha) and 3/4th P_2O_5 (45 kg P_2O_5/ha) with bioinoculants *i.e. Azotobacter* and Phosphate Solubilizing Bacteria (PSB). The results revealed that the vigorous growth in terms of plant height (167.40 cm), number of branches per plant (43.20), plant spread (N-S) (102.60 cm) and dry matter content of plant (68.40%) was noted significantly in plants treated with *Azotobacter* + PSB + 3/4th dose of N + full dose of P_2O_5 (T_{15}). The plant receiving same treatment recorded maximum flower diameter (6.60 cm), stalk length (24.70 cm), number and weight of petals per plant (189.90 and 2.93 g, respectively), vase life (5.40 days), maximum number of flowers/plant (42.20), weight of flowers/plant (147.50 g) and yield of flowers (137.40 q/ha). Biofertilizers along with chemical fertilizers found beneficial for vigorous growth of plant and for maximum yield of better quality flower in African marigold.

INTRODUCTION

Marigold (*Tagetes erecta* L.) is one of the most important hardy flower crop grown commercially in different parts of the world. In India, it is one of the most commonly grown loose flowers and extensively used on religious and social functions in different forms. Both, leaves and flowers of marigold are also equally important from medicinal point of view. The flower contains abundant amount of a valuable antioxidant compound called lutein which is a carotenoid pigment mainly used as nutritional supplement, protects from sun damage, prevents LDL cholesterol from oxidizing and lowers risk of heart diseases and protects eyes thus helps decreasing night blindness and increasing vision ability (Singh and Karki, 2006).

For maximization of yield and quality of any flower crop, fertilization especially with proportion is to be properly followed. Continuous use of inorganic fertilizers has resulted in ecological imbalance with consequent ill effect on soil and environment. To maintain long term soil health and productivity there is a need for integrated nutrient management through manures and biofertilizers apart from costly chemical fertilizers for better yield of the crop (Mondal *et al.,* 2003). Biofertilizers are the new cost effective renewable source of plant nutrients to supplement chemical fertilizers. It has a crucial role in augmenting nutrient supply to crops by increasing the nutrient availability through exploitation of natural processes like biological N fixation, solubilization of insoluble P, decomposition and recycling of organic wastes etc. The use of bioinoculants like *Azotobacter*, Phosphate Solubilizing Bacteria (PSB) is a recent attempt in important of yield of different crops. Hence, the investigation was undertaken to study their effect on growth, yield and quality of African marigold cv. Pusa Narangi Gainda.

MATERIALS AND METHODS

The experiment was conducted at Floriculture Research Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The soil of experimental field was deep black soil predominant with montmorillonite clay minerals by its origin and rich in organic matter and potash, with low available nitrogen and moderate phosphorus having good water holding capacity with moderate drainage. Sixteen treatment combinations consisting two levels of nitrogen *i.e.* full N (200 kg N/ha) and 3/4th N (150 Kg/ha) and two levels of Phosphorus *i.e.* full P_2O_5 (60 kg P_2O_5/ha) and 3/4th P_2O_5 (45 kg P_2O_5/ha) with bioinoculants *i.e. Azotobacter* and Phosphate Solubilizing Bacteria (PSB) were laid out in Randomized Block Design (RBD) with three replications. African marigold cv. 'Pusa Narangi Gainda' is propagated by seeds. Slurry of *Azotobacter* and PSB was prepared alone in pots and rooted seedlings were dipped in this solution as per treatments for 20 minutes and transplanted at 60 cm x 45 cm spacing in the field. The observations on vegetative and flowering parameters were recorded and statistically analysed. The data was analysed as advocated by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

It is apparent from the data presented in Table 1, that all the

Table 1: Effect of bioinoculants on vegetative growth attributes in African marigold cv. Pusa Narangi Gainda

Treatment	Plant height (cm)	No. of branches/ plant	Plant spread (NS direction) (cm)	Dry matter content of plant (%)
T_1 - Full N 200 kg/ha + Full P_2O_5 60 kg/ha	132.7	30.0	83.7	48.6
T_2 - Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	153.2	37.2	92.7	41.5
T_3 - 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	154.5	27.2	63.5	39.9
T_4 - 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	154.7	30.7	91.7	53.0
T_5 - PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	135.0	32.3	91.7	53.7
T_6 - PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	142.9	27.5	80.0	51.1
T_7 - PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	154.7	31.7	90.0	46.9
T_8 - PSB + 3/4th N 150 kg/ha + 3/4th P_2O_5 45 kg/ha	154.3	33.0	78.2	52.5
T_9 - *Azotobacter* + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	153.2	31.0	76.7	49.9
T_{10} - *Azotobacter* + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	152.5	27.8	80.2	42.9
T_{11}- *Azotobacter* + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	146.5	38.4	88.5	54.3
T_{12}- *Azotobacter* + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	159.0	38.8	88.3	59.2
T_{13} - *Azotobacter* + PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	157.4	35.2	94.0	59.8
T_{14} - *Azotobacter* + PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	147.7	35.0	90.3	48.5
T_{15} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	167.4	43.2	102.6	68.4
T_{16} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	160.4	39.0	93.5	63.8
S.Em. +	5.64	2.25	3.05	4.67
CD at 5%	16.28	6.50	8.82	13.49

Table 2: Effect of bioinoculants on yield parameters in African marigold cv. 'Pusa Narangi Gainda'

Treatment	Days to flowering	No. of flowers/plant	Weight of flowers/ plant(g)	Yield of flowers (q/ha)
T_1 - Full N 200 kg/ha + Full P_2O_5 60 kg/ha	61.3	28.8	122.3	113.2
T_2 - Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	63.3	34	114.4	105.9
T_3 - 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	59.7	35.2	122.3	113.2
T_4 - 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	60.7	32.9	106.3	98.4
T_5 - PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	55.3	33.7	122.7	113.5
T_6 - PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	53	34.1	113.4	105
T_7 - PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	54	34.8	110.4	101.6
T_8 - PSB + 3/4th N 150 kg/ha + 3/4th P_2O_5 45 kg/ha	52.3	35.6	123.7	114.6
T_9 - *Azotobacter* + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	51.3	35.4	121.8	115.7
T_{10} - *Azotobacter* + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	53.3	31.3	123.1	114
T_{11} - *Azotobacter* + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	53	38.8	126	101.4
T_{12} - *Azotobacter* + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	48	37.1	114.3	111.4
T_{13} - *Azotobacter* + PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	49.7	35.9	145.6	134.8
T_{14} - *Azotobacter* + PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	53	33.8	126.2	116.7
T_{15} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	43.3	42.2	147.5	137.4
T_{16} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	49	39.1	133.7	123.7
S.Em. +	3.07	2.18	7.7	7.09
CD at 5%	8.86	6.3	22.24	20.48

vegetative growth attributes were significantly affected by different treatments. The highest plant height (167.40 cm), maximum number of branches (43.20), plant spread in north south direction (102.60 cm) and maximum dry matter content of plant (68.40%) were found in the plants provided with *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha. However, lowest plant height (132.70 cm) was recorded with Full N 200 kg/ha + Full P_2O_5 60 kg/ha while number of branches per plant (27.20), plant spread (63.50 cm) and dry matter content of plant (39.90 %) were found minimum in the plants treated with 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha (T_3). Increase in growth may be attributed to the fact that *Azotobacter* is free living bacterium and has specific role in fixing atmospheric N in soil which enhances the soil fertility (Vyas *et al.*, 1998). Likewise, PSB increase availability of fixed as well as applied phosphorus to the plant. Bioinoculants also produce the growth stimulating substances *viz.*, auxin, gibberellin and cytokinins which contribute towards vigorous growth of the plant. Similar findings were also reported by Suthar (2005) in African marigold, Panchal (2006) in China aster and Khan and Pariari (2012) in chilli.

The yield of flowers was significantly influenced by the application of bioinoculants with different levels of chemical fertilizers (Table 2). The plants treated with *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha (T_{15}) required minimum days (43.30) for first flower bud initiation which was statistically at par with T_{12}, T_{16}, T_{13} and T_9 whereas maximum days (63.30) taken for first flower bud initiation was observed with treatment Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha (T_2). Early flowering might be due to the effect of bio fertilizers creating a conducive source sink relationship. It caused an increase in the synthesis of cytokinin in the root tissue and its simultaneous transport to axillary buds would have resulted

Table 3: Effect of bioinoculants on quality of flower in African marigold cv. 'Pusa Narangi Gainda'

Treatment	Flower diameter (cm)	Weight of petals/ flower(g)	Number of petals/ flower	Vase life (days)
T_1 - Full N 200 kg/ha + Full P_2O_5 60 kg/ha	5.3	1.94	137.7	4.6
T_2 - Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	5.2	1.75	131.0	4.9
T_3 - 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	5.5	1.81	133.7	5.5
T_4 - 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	5.5	1.92	120.9	5.1
T_5 - PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	5.4	1.92	126.3	5.1
T_6 - PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	5.5	1.93	131.9	4.3
T_7 - PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	5.3	1.86	137.3	5.5
T_8 - PSB + 3/4th N 150 kg/ha + 3/4th P_2O_5 45 kg/ha	5.5	1.79	125.3	5.0
T_9 - *Azotobacter* + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	5.5	1.87	133.4	4.5
T_{10} - *Azotobacter* + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	5.3	2.51	136.4	4.5
T_{11} - *Azotobacter* + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	5.4	1.82	137.8	5.9
T_{12} - *Azotobacter* + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	6.0	2.66	157.8	5.1
T_{13} - *Azotobacter* + PSB + Full N 200 kg/ha + Full P_2O_5 60 kg/ha	6.0	2.66	159.5	3.8
T_{14} - *Azotobacter* + PSB + Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha	5.5	2.21	155.0	4.0
T_{15} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha	6.6	2.93	189.9	5.4
T_{16} - *Azotobacter* + PSB + 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha	6.1	2.68	164.4	5.1
S.Em. +	0.26	9.28	12.02	0.24
CD at 5%	0.76	0.27	34.70	0.70

in better sink for mobilization of photo assimilates at a rapid rate. This might have helped in the early transformation from vegetative to reproductive phase. Similar results have been reported by Suthar (2005) in African marigold.

Highest number of flowers per plant (42.20) and maximum weight of flowers (147.5 g/plant) was significantly influenced by treatment *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha (T_{15}). Whereas, least number of flowers per plant (28.80) and minimum weight of flowers (106.30 g/plant) were reported in the plants treated with treatment Full N 200 kg/ha + Full P_2O_5 60 kg/ha (T_1) and 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha (T_4), respectively. The highest yield of flowers (137.4 q/ha) was registered in the treatment *Azotobacter* + PSB + 3/4th N + full dose of P_2O_5(T_{15}) which was statistically at par with T_{13} and T_{16} while minimum yield (98.4 q/ha) was observed with treatment 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha(T_4). These might be attributed to better plant growth which indirectly influenced the flower quality and consequently flower yield. Apart from N fixation, *Azotobacter* significantly enhanced uptake of Fe, Zn, Cu and Mo (Awasthi *et al.*, 1998) and hastened flowering and yield. This could also be explained in terms of improved physical and chemical condition of the soil and increased population of micro organism which gave synchronized effect and enhanced flower yield (Singh and Singh, 2003). These results are in accordance with Suthar (2005) in African marigold and Panchal (2006) in China aster, Rathod *et al.* (2002) in gaillardia.

The data presented in Table -3 revealed the significant variation due to different treatments on flower quality of African marigold. Biggest flower diameter (6.60 cm) and maximum number of petals (189.90) were significantly observed by the plants receiving *Azotobacter* + PSB with 3/4th dose of N and full dose of P_2O_5 (T_{15}) which were statistically at par with T_{16}, T_{13} and T_{12}. However, smallest flower (5.20 cm) and least number of petals (120.90) were showed in treatment Full N 200 kg/ha + 3/4th P_2O_5 45 kg/ha (T_2) and 3/4th N 150 kg/ha + 3/4thP_2O_5 45 kg/ha (T_4), respectively. This could be due to better nutrient uptake, higher photosynthesis, source - sink relationship, besides excellent physiological and biological activities due to presence of *Azotobacter* and PSB (Gayathri *et al.,* 2004). The maximum weight of petals (2.93 g) was noted in treatment *Azotobacter* + PSB + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha (T_{15}) which was statistically at par with T_{16}, T_{13} and T_{12}. However, minimum weight of petals was recorded in T_2 being 1.75 g. This might be due to bigger sized flower and more number of petals per flower. The results are in agreement with those of Kumar *et al.* (2003) in China aster, Rathod *et al.* (2002) in gaillardia.

The maximum Vase life (5.9 days) was significantly observed in the plants treated with Azotobacter + 3/4th N 150 kg/ha + Full P_2O_5 60 kg/ha (T_{11}) which was statistically at par with T_7, T_3 and T_{15}. Treatment T_{13} recorded lowest vase life of 3.8 days. This could be due to synthesis of cytokinin by *Azotobacter* which decreased sensitivity of plant tissue to ethylene (Salunke *et al.*, 1990). Similar results were inconsonance with the findings of Suthar (2005) in African marigold and Panchal (2006) in China aster.

Considering the above results of the experiment, it is concluded that application of bioinoculants along with chemical fertilizer is more beneficial for vegetative growth and flower attributes. The African marigold cv. 'Pusa Narangi Gainda' when fed with *Azotobacter* + PSB + 3/4th dose of N + full dose of P_2O_5 produced vigorous growth and consequently induced early flowering with better flower quality and maximum flower production.

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