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Studies on impact of bio-fertilizers and GA_3 on growth and flower yield of marigold (*Tagetes erecta* L.) cv. ORANGE DOUBLE

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Abstract : Marigold is grown for loose flowers, making garlands, decoration during pooja and several religious functions besides its use in landscape gardening. The present investigation was carried out to know the effect of bio-fertilizers and GA_3 on growth and flower yield of marigold. The treatment T_{14} (*Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm) recorded more plant height, maximum stem girth, more dry matter production in stem, leaf and flower than other treatments. The same treatment T_{14} also recorded significantly more diameter of flower, number of flowers per plant, yield per plot (6.45 kg) and yield per ha (9.83 t) than control.

Key words : Bio-fertilizers, GA_3, Growth parameters, Yield attributes, Marigold

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Marigold, which is also known as "Tagetes" is one of the commercially exploited flower crops that belong to the family Asteraceae and genus *Tagetes*. In India, marigold is cultivated on an area of 20,825 hectares with a production of more than 2 lakhs tonnes. In Karnataka, it is grown over an area of 6,985 ha with an annual production of 66,497 tonnes which shares 24 per cent of area out of the total flower production area in Karnataka (Anonymous, 2009). The use of only fertilizers is also not sufficient to increase the flower yield as applied fertilizers containing major nutrients especially N may lost through leaching or evaporation and P may be fixed in the soil in complex form and thus both N and P availability are in lesser quantity to the crop which may be insufficient for the plant to show its maximum potentiality for producing higher yield. In order to improve deficient status of N and P in soil, the use of bio-fertilizers like *Azospirillum* which fixes atmospheric nitrogen in the soil and phosphate solublising bacteria (PSB) which releases P from fixed complex forms in the soil and thus maintaining the nutrient reserve of the soil which is helpful for getting higher yield of flower. The use of bio-fertilizers also reduces inorganic fertilizers to an extent of 25 per cent. Keeping these points in view, an investigation was undertaken to find out the possibilities of increasing flower yield and seed yield through the use of bio-fertilizers and GA_3 under North Eastern dry zone of Karnataka. The bio-fertilizers were inoculated to the seedlings by dipping the seedlings at the time of transplanting as per the treatments. The GA_3 sprayed twice (30 and 60 DAT) as per the treatments.

RESEARCH METHODS

The field experiment was laid out in RBD design with three replications in red soil during the year 2010-2011 at MARS Raichur. Totally 15 treatments were formed by bio-fertilizers and GA_3. The variety Orange Double was used for the studies. The size of the net plot size of 2.4 x 2.7 m was obtained after removing one ring line. 30 days old seedlings were used for transplanting. Although the observations on growth and yield parameters were recorded at 50,100 and 150 days after transplanting, only the final observations on these parameters are presented here. Flower yield was recorded weekly after harvest. Statistical analysis was made for both growth and yield parameters as per the standard statistical procedures.

RESEARCH FINDINGS AND DISCUSSION

In the present study, among the various treatment combinations of bio-fertilizers and GA_3 combinations tried, the maximum flower yield (9.83 t ha^{-1}) was recorded with the treatment T_{14} (*Azospirillum* @ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm) and was significantly superior to all other treatments except the treatment T_{15}(9.23), T_{13}(9.18) and T_8(9.20). The treatment without bio-fertilizer and GA_3 (T_1) had recorded significantly lower yield (7.83 t ha^{-1}).The increase in yield in the treatment T_{14} and T_8 might be due to the beneficial effects of bio-fertilizers in combination with GA_3. The significantly higher values for yield due to spray of GA_3 200 ppm was because of enhanced reproductive efficiency and photosynthesis (Sunitha, 2006). Similar findings were also obtained by Benzaminmathew and Singh (2003) in marigold, Prabhatkumar *et al*. (2003) and Chitra and Patil (2007) in China aster.

The difference in the flower yield per hectare due to the influence of bio-fertilizer and GA_3 could be related to their flower yield per plot and flower yield per plant (Table 4) which showed significant varying differences as that of flower yield per hectare which confirms the higher flower yield (t ha^{-1}) in the treatment T_{14} and T_{15} might be due to higher flower yield per plot. Similar results were obtained with use of bio-fertilizers and GA_3 in different crops like marigold (Velmurgan,1998; Sunitha, 2006) and China aster (Prabhatkumar, 2003).

The higher yield per plant may be attributed to the higher number of flowers per plant. Significantly maximum number of flowers per plant were produced in the treatment T_{14} (61.67) as compared to control. The more flower yield (t ha^{-1}) in T_{14} was due to increased number of flowers per plant. These results are in conformity with the findings of Nethra (1996) in China aster, Ajitkumar (2002) in marigold and Shashikanth (2005) in marigold.

The higher flower yield (t ha^{-1}) is a manifestation of other yield contributing characters like weight of flower (10 flower weight). The treatment T_{14} recorded maximum 10 flower weight (49.00 g) and was significantly superior to control (T_1). The other treatments like T_{15} was also significantly superior to control. Hence, the increase in 10 flower weight in T_{14} and T_{15} treatments might be due to the beneficial effects of bio-fertilizer in combination with GA_3 (Table 3). Similar trend of higher 10 flower weight in the treatments of *Azospirillum*, PSB was reported by Chitra and Patil (2007) in China aster.

The diameter of the flower as another yield attributing

Table 1 : Effect of bio-fertilizers and GA_3 on growth parameters in marigold

Treatments	Plant height (cm)	Stem girth (cm)	Number of branches
T_1: Control (RDF)	77.13	1.63	13.07
T_2: *Azospirillum* @ 5 kg ha^{-1}	85.67	1.82	18.07
T_3: PSB @ 5 kg ha^{-1}	84.47	1.79	17.67
T_4: GA_3 @ 100 ppm	87.27	1.83	18.13
T_5: GA_3 @ 200 ppm	96.40	1.91	19.40
T_6: GA_3 @ 300 ppm	88.20	1.84	18.27
T_7: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 100 ppm	90.33	1.83	18.60
T_8: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 200 ppm	100.60	2.20	20.87
T_9: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 300 ppm	89.20	1.85	18.80
T_{10}: PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	89.40	1.83	18.07
T_{11}: PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	97.47	2.04	19.67
T_{12}: PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	89.47	1.87	18.13
T_{13}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	91.27	1.87	18.53
T_{14}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	107.80	2.44	25.47
T_{15}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1}+ GA_3 @ 300 ppm	91.07	1.87	18.40
S.E. ±	4.24	0.10	1.27
C.D. (P=0.05)	12.29	0.29	3.69

DAT- Days after transplanting, PSB - Phosphate solubilizing bacteria
GA_3 sprayed at 30 and 60 DAT

character influenced much by the treatments formed by the bio-fertilizers and GA_3. The treatment T_{14} (5.7 cm) with T_{15},T_{13} and T_8 recorded significantly more diameter of flower than control (4.3 cm). Hence, the higher flower yield in these treatments might be due to better size of flowers. The similar results were obtained by Chaitra and Patil (2007) in China aster.

The 50 per cent flowering as part of the duration of flowering influencing the flower yield (t ha^{-1}) was also varied significantly due to the influence of bio-fertilizers and GA_3. The treatments T_5 (50.21), T_{14} (52.33), T_8 (53.47), T_{11} (53.33), T_{15} (53.30) recorded early flowering as compared to T_1 (57.00) which might be due to beneficial effect of bio-fertilizers and GA_3. The early flowering due to action of bio-fertilizers was quoted by Shubha (2006) in marigold, while earlier flowering due to action of GA_3

Table 2 : Effect of bio-fertilizers and GA_3 on growth parameters in marigold

Treatments	Number of leaves	Leaf area (cm^2)	Total dry matter accumulation(g plt^{-1})
T_1: Control (RDF)	140.40	943.40	65.22
T_2: *Azospirillum* @ 5 kg ha^{-1}	160.53	968.93	72.78
T_3: PSB @ 5 kg ha^{-1}	156.93	966.33	75.00
T_4: GA_3 @ 100 ppm	161.73	969.80	69.74
T_5: GA_3 @ 200 ppm	170.27	980.67	71.68
T_6: GA_3 @ 300 ppm	165.07	973.00	69.79
T_7: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 100 ppm	164.33	974.87	73.44
T_8: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 200 ppm	178.97	989.40	82.96
T_9: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 300 ppm	154.60	967.27	74.11
T_{10}: PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	163.07	974.93	74.89
T_{11}: PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	172.80	981.40	83.14
T_{12}: PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	161.73	972.07	74.33
T_{13}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	161.07	989.76	84.21
T_{14}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	194.20	993.27	99.00
T_{15}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	163.93	990.81	86.90
S.E. ±	5.06	30.97	2.83
C.D. (P=0.05)	14.68	89.72	8.21

DAT- Days after transplanting, PSB - Phosphate solubilizing bacteri GA_3 sprayed at 30 and 60 DAT

Table 3 : Effect of bio-fertilizers and GA_3 on 50 per cent flowering, flower diameter and 10 flower weight in marigold

Treatments	Days to 50% flowering (days)	Flower diameter (cm)	10 flower weight (g)
T_1: Control (RDF)	57.00	4.30	38.00
T_2: *Azospirillum* @ 5 kg ha^{-1}	54.33	4.80	44.33
T_3: PSB @ 5 kg ha^{-1}	54.67	4.83	43.67
T_4: GA_3 @ 100 ppm	54.67	4.97	43.00
T_5: GA_3 @ 200 ppm	50.21	5.10	44.00
T_6: GA_3 @ 300 ppm	55.33	5.10	42.33
T_7: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 100 ppm	54.00	5.23	43.33
T_8: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 200 ppm	53.47	5.50	46.00
T_9: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 300 ppm	52.34	5.30	43.33
T_{10}: PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	53.88	5.20	43.33
T_{11}: PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	53.33	5.53	46.33
T_{12}: PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	53.00	5.23	45.00
T_{13}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	55.67	5.61	47.67
T_{14}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	52.33	5.70	49.00
T_{15}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	53.30	5.66	48.67
S.E. ±	2.07	0.37	2.56
C.D. (P=0.05)	6.01	1.09	7.43

was narrated by Sunitha (2006) in marigold.

The difference in the flower yield and yield components due to bio-fertilizers and GA_3 could be related to the differences in plant growth characters.

The plant height (cm) was influenced significantly by different treatments formed by bio-fertilizers and GA_3 (Table 1). The treatment T_{14} recorded more plant height (107.80 cm) and was found at par with T_8 and T_{11}. The increase in the plant height due to bio-fertilizer treatments might be due to ability of the *Azospirillum* to fix more N as required for vegetative growth. Similar trend of higher plant height (cm) in treatments with *Azospirillum* and PSB was also obtained by Velmurugan (1998), while higher plant height with GA_3 was reported by Sunitha

Table 4 : Effect of bio-fertilizers and GA_3 on number of flowers per plant, flower yield per plant, flower yield per plot and flower yield per hectare in marigold

Treatments	Number of flowers per plant	Flower yield per plant (kg)	Flower yield per plot (kg)	Flower yield per ha (t)
T_1: Control (RDF)	49.00	0.21	5.01	7.83
T_2: *Azospirillum* @ 5 kg ha^{-1}	52.33	0.22	5.34	8.28
T_3: PSB @ 5 kg ha^{-1}	51.67	0.22	5.28	8.16
T_4: GA_3 @ 100 ppm	53.33	0.23	5.44	8.45
T_5: GA_3 @ 200 ppm	54.67	0.24	5.68	8.79
T_6: GA_3 @ 300 ppm	54.33	0.23	5.51	8.50
T_7: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 100 ppm	56.67	0.24	5.79	8.76
T_8: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 200 ppm	58.43	0.25	5.96	9.20
T_9: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 300 ppm	57.33	0.24	5.86	9.08
T_{10}: PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	55.33	0.24	5.66	8.70
$T_{1\,1}$: PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	57.33	0.24	5.86	9.09
T_{12}: PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	56.33	0.24	5.75	8.90
T_{13}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	58.33	0.25	5.91	9.18
T_{14}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	61.67	0.27	6.45	9.83
T_{15}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	59.67	0.25	6.10	9.23
S.E. ±	2.82	0.01	0.27	0.55
C.D. (P=0.05)	8.17	0.03	0.80	1.60

Table 5 : Economics of marigold cultivation as influenced by bio-fertilizers and GA_3

Treatments	Flower yield per ha (t)	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C (ratio)
T_1: Control (RDF)	7.83	1,56,600	38,020	1,18,580	3.1
T_2: *Azospirillum* @ 5 kg ha^{-1}	8.28	1,65,600	38,270	1,27,330	3.3
T_3: PSB @ 5 kg ha^{-1}	8.16	1,63,200	37,770	1,25,430	3.3
T_4: GA_3 @ 100 ppm	8.45	1,69,000	38,371	1,30,629	3.4
T_5: GA_3 @ 200 ppm	8.79	1,75,800	40,973	1,34,827	3.2
T_6: GA_3 @ 300 ppm	8.50	1,70,000	41,825	1,28,175	3.1
T_7: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 100 ppm	8.76	1,75,200	39,121	1,36,079	3.4
T_8: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 200 ppm	9.20	1,84,000	40,473	1,43,527	3.5
T_9: *Azospirillum* @ 5 kg ha^{-1} + GA_3 @ 300 ppm	9.08	1,8,1600	42,325	1,39,275	3.2
T_{10}: PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	8.70	1,74,000	39,121	1,34,879	3.4
T_{11}: PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	9.09	1,81,800	41,223	1,40,577	3.4
T_{12}: PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	8.90	1,78,000	42,075	1,35,925	3.2
T_{13}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 100 ppm	9.18	182600	40,071	1,43,529	3.5
T_{14}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm	9.83	1,96,600	41723	1,54,877	3.8
T_{15}: *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + GA_3 @ 300 ppm	9.23	1,84,600	42,575	1,42,025	3.4

(2006) in marigold, Chitra and Patil (2007) and Sushma (2008) in China aster.

The stem girth of plant was significantly influenced by the bio-fertilizer and GA_3.The significantly maximum stem girth was recorded in the treatment T_{14} over the rest of the treatments except the treatments T_8 and which could be attributed to better nutrient flow into plants supplied with bio-fertilizers and further accumulation in that part. Similar trend of maximum stem girth was also obtained by Wange and Patil (1994) in marigold.

The branches as the skeletal structure of the plant were recorded more in the treatment T_{14} (25.47) over rest of the treatments except the treatments T_8 (20.87). The increase in the number of branches in this treatment could be attributed to better nutrient flow into plants with bio-fertilizer and GA_3 spray there by favouring formation of auxiliary buds resulting in more number of branches (Nethra, 1996).

With regards to leaves as food manufacturing factory of plant and leaf area a site for photosynthesis were significantly influenced by the treatments (Table 2). The treatments T_{14} recorded more number of leaves and leaf area than control. Thus more number of leaves and leaf area meant for higher photosynthesis under this treatment might be due to increase in the number of branches and enhanced leaf area due to the action of growth promoting substances produced by bio-fertilizers. Similar results were reported by Chitra and Patil (2007) and Sushma (2008) in China aster.

Significantly higher total dry matter accumulation was obtained in the treatment T_{14} over rest of the treatments except T_{15} and T_{13}. The increase in the total dry matter production in these treatments could be related to increase in dry matter accumulation in stem, leaf and flower due to favourable effect of bio-fertilizers and GA_3. Similar findings were reported by Velmurugan (1998) in marigold, Chitra and Patil (2007) and Sushma (2008) in China aster.

The effect of bio-fertilizers *viz.*, *Azospirillum* and PSB in enhancing the growth and yield parameter of marigold may be due their ability to produce growth promoting substances (IAA, giberellin like substances), vitamins B (B_{12}, thiamine, riboflavin) as reported by Wange and Patil (1994). The increase in growth parameter with application of GA_3 seems to be due to enhanced cell division and cell enlargement, promotion of protein synthesis, breaking of the apical dominance resulting in excellent growth and flowering parameters which directly enhanced the yield attributing characters.

The acceptance of innovative technology by the farmers ultimately depends on the economics involved in the production of crop. In the present investigation, higher gross returns of Rs. 1,96,600 ha^{-1} and net returns of Rs. 1,54,877 ha^{-1} with better B:C ratio of 3:8 was obtained with the treatment of *Azospirillum* @ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm (T_{14}) (Table 5). The overall results have proved that the treatment T_{14} (*Azospirillum* @ 5 kg ha^{-1}+ PSB @ 5 kg ha^{-1} + GA_3 @ 200 ppm) was found beneficial in increasing the flower yield in marigold crop. From the present investigation it was clear that bio-fertilizers like *Azospirillum*, PSB and GA3 as growth regulator can be used increasing the flower yield with better quality.

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