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Effect of biofertilizers on growth, flower yield and quality of marigold (*Tagetes erecta* L.) cv. Arka Bangara 2

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Abstract
A field experiment entitled "Effect of biofertilizers on growth, flower yield and quality of marigold (*Tagetes erecta* L.) cv. Arka Bangara 2"was conducted in the research block of Department of Floriculture and Landscape Architecture, College of Horticulture, Bengaluru, during the *rabi* season from September 2020 to December 2020. The experimental material consisted four different bio-fertilizers *viz., Azotobacter*, Phosphate Solubilizing Bacteria, Potassium Solubilizing Bacteria and Arbuscular Mycorrhiza which were evaluated for growth, yield and quality parameters. The experiment consisted of 9 different treatments laid out in Randomized Complete Block Design with three replications. The maximum increase in vegetative growth parameters like plant height, number of primary branches per plant, leaf area, stem girth were recorded in T_5 (100% NPK + *Azotobacter* + PSB + AM fungi + KSB). Whereas, the maximum flowering and yield parameters like days to first flowering, duration of flowering (days), days to 50 per cent flowering, number of flowers per plant, average weight of flower including flowering yield per plant and flower yield per hectare and also quality parameters like xanthophyll content and shelf life were recorded in T_9 (75% NPK + *Azotobacter* + PSB + AM fungi + KSB) among different treatments of biofertilizers.

Keywords: *Azotobacter*, PSB, KSB, Am fungi, NPK, marigold

Introduction
Marigold is a hardy and versatile flower crop, commonly called as "Rose of Indies" belongs to the family Asteraceae andnative to Mexico, having genus *Tagetes* spp. *Tagetes* named after demi god ' Teges' which means beauty. The genus consists of 33 species of strongly scented annual and perennial herbs, out of which two species *viz.*, *Tagetes erecta* (African marigold) and *Tagetes patula* (French marigold) are commercially cultivated. Marigold produce flowers of wide spectrum of attractive colours, shape, size with longer blooming period and excellent keeping quality. It has habit of free flowering and short duration to produce marketable flowers. Apart from loose flower and landscape uses, it is also having medicinal properties. Leaf paste is used externally against boils and carbuncles. Leaf extract is a good remedy for ear ache and has fungicidal effect. Roots exudates contains HCN compound *i.e.*, α-tri terthenal which is effective against nematodes and hence, it is used as trap crop to control nematodes (Datta, 2019) [2]. Nowadays, it is also gaining importance in poultry, fisheries, cosmetics and textile industries as it contains xanthophyll, which is used to increase intensity of yellow colour of egg yolk in poultry, fish meat in fisheries and also as a colouring agent in bakery and confectionary.
Marigold flower production and quality are influenced mainly by climatic, geographical and nutritional factors. Among them, nutritional factor is playing a major role in improving the quality and productivity of marigold, as these nutrients are supplied mainly through chemical fertilizers. The indiscriminate and continuous use of chemical fertilizers alone to the soil leads to imbalance of nutrients in soil which adversely affect the soil health, soil fertility as well as nutrient uptake efficiency of crops, besides, affecting the yield and quality of the flowers. The use of chemical fertilizers has to be reduced to check the soil and water pollution and simultaneously, the role of beneficial soil microorganisms has to be augumented by different ways such as use of application of biofertilizers. Biofertilizers are eco-friendly, they can be applied to all the crops in association with other biofertilizers without any antagonistic effect with low cost input. Biofertilizers not only improve the crop growth and yield but also

improve flower quality and fertilizer use efficiency. These supplement the major plant nutrients and improve the plant productivity for sustainable agriculture (Mohd and Khan, 2014) [13]. The use of these products has not been popular among farmers either due to lack of awareness or availability and supply of quality biofertilizers. In the view of above, the production and use of biofertilizers along with organic manures assume greater significance and could be an excellent alternative to chemical fertilizers.

Material and Methods

An experiment was conducted in *rabi* season from September 2020 to December 2020, at research block of Department of Floriculture and Landscape Architecture, College of Horticulture, Bengaluru. The research farm is situated under Eastern Dry Zone of Karnataka. Which is geographically situated at 12.97° North Latitude and 77.59° East Longitude with an altitude of 942.37 m above mean sea level. The mean annual rain fall is 859 mm. Whereas, the mean maximum temperature is 32.8 °C, minimum temperature 14.6 °C.

The statistical design Randomized Complete Block Design (RCBD) was used which containing nine treatments with three replications. The 4 bio-fertilizers *viz., Azotobacter*, Phosphate Solubilizing Bacteria, Potassium Solubilizing Bacteria and Arbuscular Mycorrhizal fungi were used along with different doses of N, P, K in different plots of marigold with the spacing of 60 cm X 45 cm. The field was maintained under uniform recommended cultural practices. The variety used here is ArkaBangara 2, released from IIHR, having flowers of yellow gold colour, early flowering with compact and large size flowers. Treatment details are presented in table 1.

Table 1: Treatment details

Treatment notation	Treatment content
T_1	100% NPK (225:60:60 kg of N P_2O_5 K_2O ha^{-1})
T_2	100% N + *Azotobacter*
T_3	100% NP + *Azotobacter* + PSB
T_4	100% NPK + *Azotobacter* + PSB + AM fungi
T_5	100% NPK + *Azotobacter* + PSB + AM fungi + KSB
T_6	75% N +100% PK + *Azotobacter*
T_7	75% NP +100% K + *Azotobacter* + PSB
T_8	75% NP +100% K + *Azotobacter* + PSB + AM fungi
T_9	75% NPK + *Azotobacter* + PSB + AM fungi + KSB

Result and Discussion

The results of the present study showed significant variation among the different characters studied. The maximum plant height at different stages of the crop growth was significantly influenced by application of biofertilizers. The treatment $T_5$with 100 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, AM fungi and KSB) recorded significantly taller plants of 32.40 cm, 51.91 cm and 67.20 cm at 30 DAT, 60 DAT and at grand growth stage (90 DAT) respectively. The taller plants produced in treatment T_5 might be due to the combined effect of inorganic fertilizers, bioinoculants and FYM. This might be attributed to biological nitrogen fixation, production of growth substances and also solubilization of native phosphorus by bioinoculants. The combined effect triggered the plant metabolic activities and photosynthetic efficacy, leading to the better growth and development of crop plant. These observations were in line with the findings of Dhiraj *et al*. (2009) [3] in marigold.

The number of primary branches per plant were significantly influenced by biofertilizers application (Table 2). Significantly more number of primary branches per plant (8.67) were found due to the treatment T_5 (8.67, 8.93 and 9.00) at 30, 60 and 90 days after transplanting. The treatment T_1 recorded less number of primary branches per plant. The combination of RDF along with *Azotobacter*, PSB and KSB were mutually benefited with each other and supplied essential nutrients to plants and hence, resulted in production of more branches per plant. The results are in confirmation with the findings of Koshika *et al.* 2018 [9] in marigold.

Significantly maximum stem girth of 2.33 cm was observed in the treatment $T_5$with 100 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB). The enhanced stem girth in treatment T_5 might be due to application of biofertilizers which might have involved in synthesis and secretion of organic acids and other growth promoting substances like IAA and gibberellins that increased the water uptake by plant, promoted the root growth and thus helped in better plant growth and also KSB might have enhanced the availability of potash and promoted the stem growth. These results are in conformity with those findings of Godse *et al.* (2006) [6] in gladiolus.

The leaf area was significantly influenced by application of biofertilizers (Table 2). Significantly higher leaf area of 11.04 cm^2 was registered in the treatment T_5 with 100 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB). Whereas, significantly lesser leaf area of 9.03 cm^2 was registered in the treatment T_1 as control. This might be due to use of biofertilizers in combination with NPK resulted in good nutrition which might have helped in better root proliferation and increased uptake efficiency of water and nutrients lead to increased photosynthesis activity, increased cell division and enlargement and resulted in more leaf area. These results are in confirmity with the findings of Maninderpal *et al.* (2017) [11] in china aster.

Days taken for the appearance of first flowering, 50 per cent flowering and flowering duration were significantly influenced by application of biofertilizers (Table 3).The treatment $T_9$with 75 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB) took significantly less number of days (41.57 days) for the appearance of first flower, less number of days (64.40 days) for 50 per cent flowering, and also shown maximum duration of flowering (70.00 days) compare to other treatments. Earliness in flowering is because of the easy uptake of nutrients by plants and also simultaneous transport of growth promoting substances like auxins, gibberellins, cytokinins, vitamins and organic acids produced by biofertilizers to the axillary buds. This result was in accordance with Kumari *et al.* (2019) [10] in marigold. An adequate supply of phosphorus in the early stages of crop growth is important for laying down the primordial for reproductive parts of the plant and helps in early maturity of crops. Ultimately, this has resulted in a better sink for quick mobilization of photosynthates and early transformation from vegetative to reproductive phase. Similar results were obtained by Parolekar *et al.* (2012) [16] in tuberose. And also the variation in duration of flowering due to inoculation of plant roots with biofertilizers and application of VAM to soil which results in better nutrient uptake, which leads to accumulation of more photosynthesized food resulted in more duration of flowering. The similar results were observed by Divya *et al.* (2019) [4] in zinnia.

The number of flowers per plant were significantly influenced by application of biofertilizers (Table 3).The treatment T_9 with 75 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB) recorded significantly more number of flowers per plant (66.93). While, least number of flowers per plant (54.73) was observed in the treatment T_2 with RDF 100 per cent N and *Azotobacter*. This is due to suppression of luxurious vegetative growth and induction of reproductive stage. The treatment T_9 might have influenced the better growth which in general has significant positive correlation with flowering and yield parameters. These results are in confirmity with the findings of Radhika *et al.* (2010) [17] in marigold. The increase in number of flowers might be due to possible role of *Azotobacter* through atmospheric nitrogen fixation, better root proliferation, uptake of nutrients and water. It is also attributed to the increase availability of phosphorus and potassium. In addition, KSB are also known to produce amino acids, vitamins and growth promoting substance like indol-3-acetic acid (IAA) and gibberellic acid (GA_3) which helps in better growth of the plants which ultimately contribute to increase in the yield. Similar improvement in yield attributes was reported by Palagani *et al.* (2013) [15] in chrysanthemum and Thumar *et al.* (2013) [18] in marigold.

The average weight of the individual flower including flowering yield per plant and flower yield per hectare differed significantly due to the application of biofertilizers (Table 2).

Significantly maximum average individual weight of flower (8.45 g), maximum flower yield per plant (569.22 g) and per hectare (18.97 t ha-1) was registered in the treatment T_9. While, minimum weight of flower (7.59 g), was documented in the treatment T_1. Whereas, the minimum flower yield per plant (426.13 g) and per hectare (14.20 t ha-1) was observed in the treatment T_2 with RDF (100 per cent N) and *Azotobacter*.

An increase in flower weight and maximum flower yield might be due to optimal availability of NPK along with all the other essential flower inducing nutrients. Nitrogen promotes protein synthesis which in turn promotes the development of floral primordial. Phosphorus is also responsible for formation of floral primordial. Their ample suppliment by biofertilizers resulted in increased weight of individual flower. These observations are in conformity with the findings of Kishore *et al.* (2018) [8] in marigold and also, flower yield due to NPK, which have N fixing and P solubilizing proficiency and K availabilizing along with secretion of growth promoting substances. This results in more number of flowering branches might have increased the number of flowers which in turn increased flower yield. Similar results were found by Maninderpal *et al.* (2017) [11] in China aster and Abhinav and Ashok (2013) [1] in marigold.

Significantly maximum xanthophyll content (34.59 mg g^{-1}) was recorded in the flowers obtained by treatment T_9. Whereas, minimum xanthophyll content (22.08 mg g^{-1}) of flower was registered in the treatment T_1.The carotenoid content was significantly influenced by the application of inorganic fertilizers along with biofertilizers, which is due to addition of nitrogen and increased production of growth hormones like NAA, GA and cytokinins. These results were in confirmation with the reports of Fatemeh *et al.* (2013) [5] in marigold.

The shelflife of marigold differed significantly due to application of biofertilizers (Table 3). Significantly maximum shelflife of marigold (3.87 days) was found in the flowers obtained by treatment T_9 with 75 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB). Whereas, minimum shelf life (2.23 days) was noticed in the treatment T_1 with 100 per cent NPK. The increased shelf life in the treatment might be due to the higher retention of water in the cells of flowers with lesser desiccation as compared to the other treatments. Similar beneficial effects of bio-fertilizers on shelf life have been reported by Mashaldi (2000) [12] in marigold, Jayamma *et al*. (2014) [7] in jasmine.

Table 2: Effect of biofertilizers on plant height, No. of primary branches per plant, stem girth and leaf area of marigold cv. Arka Bangara 2 during growth period 2020-21

Treatments	Plant height (cm)			No. of primary branches per plant			Stem girth (cm)	Leaf area (cm^2)
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT		
T_1	28.39	41.59	56.77	7.13	7.20	7.20	1.55	9.03
T_2	26.93	42.35	57.33	6.80	7.07	7.40	1.65	9.13
T_3	29.65	45.53	61.39	7.47	7.73	7.87	1.70	9.71
T_4	30.53	48.66	64.57	8.13	8.33	8.33	1.97	10.49
T_5	32.40	51.91	67.20	8.67	8.93	9.00	2.33	11.04
T_6	27.21	42.07	56.83	6.87	7.13	7.33	1.59	9.09
T_7	29.40	47.13	59.20	7.53	7.53	7.53	1.75	9.91
T_8	30.23	48.27	63.20	7.93	8.20	8.20	1.82	10.18
T_9	30.73	50.49	67.13	8.20	8.60	8.73	2.29	10.91
S.Em (±)	0.30	0.27	0.16	0.13	0.08	0.10	0.02	0.05
CD (5%)	0.90	0.81	0.49	0.39	0.25	0.30	0.06	0.15

Table 3: Effect of biofertilizers on root length (cm), diameter of flower (cm), No. of flowers per plant, average individual weight of flower (g), flower yield per plant (g), flower yield per hectare (t ha^{-1}), xanthophyll (mg g-1)and shelf life (days) of marigold cv. ArkaBangara 2 during growth period 2020 - 21

Treatments	Days to first flowering	Days to 50% flowering	Duration of flowering (days)	No. of flowers per plant	Average individual weight of flower (g)	Flower yield per plant (g)	Flower yield per hectare (t ha^{-1})	Xanthophyll (mg g^{-1})	Shelf life (days)
T_1	46.73	70.80	64.80	55.47	7.59	429.61	14.32	22.08	2.23
T_2	45.80	70.13	65.93	54.73	7.89	426.13	14.20	26.35	2.63
T_3	44.67	68.60	66.80	59.40	7.77	468.93	15.63	26.78	3.33
T_4	45.47	68.20	67.53	64.93	8.10	526.27	17.54	31.82	3.10

T_5	41.87	65.20	69.07	66.43	8.25	563.66	18.79	33.29	3.67
T_6	46.47	69.60	65.47	57.60	7.61	445.84	14.86	30.74	2.70
T_7	44.47	66.33	67.20	58.87	7.85	464.50	15.48	30.35	3.40
T_8	43.53	65.27	68.60	62.17	8.06	504.83	16.83	30.52	3.47
T_9	41.57	64.40	70.00	66.93	8.45	569.22	18.97	34.59	3.87
S.Em (±)	0.43	0.18	0.11	0.18	0.03	1.93	0.06	0.52	0.13
CD (5%)	1.28	0.54	0.33	0.55	0.09	5.78	0.19	1.57	0.40

Conclusion

From the above research it can be indicated that, an application of a recommended dosage of nitrogen, phosphorus and potassium (RDF 100% NPK) can be applied with the inoculation of biofertilizers (*Azotobacter*, PSB, VAM and KSB) besides obtaining higher flower yield. Hence, it can be concluded that a treatment comprising 75 per cent NPK along with the inoculation of the above biofertilizers (*Azotobacter*, PSB, VAM and KSB) performed better with flowering and yield attributes. Hence, the treatment T_9 with 75 per cent NPK along with the biofertilizers (*Azotobacter*, PSB, VAM and KSB) can be recommended for commercial cultivation of marigold in order to explore more yield and also to maintain better soil fertility.

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