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Effect of soil and foliar applied liquid bio-inoculants on flowering behaviour, yield and quality in African marigold grown under drip irrigation system

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Abstract
The present investigation entitled "Effect of Soil and Foliar Applied Liquid Bio-inoculants on Flowering Behaviour, Yield and Quality in African Marigold Grown under Drip Irrigation System" was carried out at Centre of Excellence, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, during the year 2022-23. The experiment was laid out in factorial randomized block design with 3 replications and 15 treatments. The results revealed that soil drenching of Phosphorous Solubilizing Bacteria @ 10% alone and foliar application of Azotobacter @ 2.5% alone and treatment combination T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) performed best with regards to early bud initiation, early 50% flowering, minimum number of days to full bloom, flower yield per hectare, flower diameter, fresh weight of flowers per plant, dry weight of flowers per plant and shelf life.

Keywords: African marigold, phosphorous solubilizing bacteria, Azotobacter, early bud initiation

Introduction
Marigold, scientifically known as Tagetes, is a genus of annual or perennial flowering plants in the daisy family, Asteraceae. These plants are native to the America, primarily Mexico and Central America, but they have been naturalized in many other regions around the world due to their popularity as ornamental plants and their various uses in traditional medicine and cultural practices. Its chromosome number is 2n=24. Marigolds are known for their bright, vibrant flowers, which come in shades of yellow, orange, and red, with some varieties also featuring maroon or mahogany tones. It has gained popularity on account of its easy culture, wider adaptability, and increasing demand in the Asian subcontinent. Sometimes, the whole plant is used for decorations. It can be planted in beds for mass display, mixed borders and can also be grown in pots. Biofertilizers found to be excellent source of plant nutrients and also improve the soil fertility and soil structure. They seem to be feasible option for quality flower production and higher yield on a commercial and profitable scale.in addition, they are eco friendly, easily available and cost effective.

Materials and Methods
The experiment was conducted at Centre of Excellence, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during the academic year 2022-23. The experiment was laid out in factorial randomized block design with 3 replications and 15 treatments viz. T_1 [SD_0 (No soil drenching) + FS_0 (No foliar spray)], T_2 [SD_0 (No soil drenching) + FS_1 (Azot) @ 2.5%], T_3 [SD_0 (No soil drenching) + FS_2 (Azos) @ 2.5%], T_4 [SD_1 (PSB) @ 10% + FS_0 (No foliar spray)], T_5 [SD_1 (PSB) @ 10% + FS_1 (Azot) @ 2.5%], T_6 [SD_1 (PSB) @ 10% + FS_2 (Azos) @ 2.5%], T_7 [SD_2 (ZSB) @ 10% + FS_0 (No)], T_8 [SD_2 (ZSB) @ 10% + FS_1 (Azot) @ 2.5%], T_9 [SD_2 (ZSB) @ 10% + FS_2 (Azos) @ 2.5%], T_{10} [SD_3 (KSB) @ 10% + FS_0 (No foliar spray)], T_{11} [SD_3 (KSB) @ 10% + FS_1 (Azot) @ 2.5%], T_{12} [SD_3 (KSB) @ 10% + FS_2 (Azos) @ 2.5%], T_{13} [SD_4 (Aceto) @ 10% + FS_0 (No foliar spray]), T_{14} [SD_4 (Aceto) @ 10% + FS_1 (Azot) @ 2.5%], T_{15} [SD_4 (Aceto) @ 10% + FS_2 (Azos) @ 2.5%] were treated. Seedlings were transplanted 30 days after transplanting and cultural practices like irrigation, weeding and pinching were done.

Results and Discussion

Number of days to 1st bud initiation

Among soil applied bioinoculants, the minimum number of days to 1st flower bud initiation (28.12 days) was observed under the treatment SD_1 (PSB @ 10%) and among foliar applied bioinoculants 27.81 days was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, the early flower bud initiation (26.83 days) was observed under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 27.20 days. Early bud initiation is due to easy uptake of nutrients and simultaneous transport of growth promoting substances they resulted in faster mobilization of photosynthates and early transformation of plant parts from vegetative to reproductive phase. And Similar results were found in the findings of Palagani *et al.* (2013) [8] in Gladiolus, Kumar and Kumar (2017) [5] in Marigold.

Number of days to 50% flowering

Among soil applied bioinoculants, the minimum number of days to 50% flowering (37.00 days) was recorded under the treatment SD_1 (PSB @ 10%) and among foliar applied bioinoculants 36.67 days was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations minimum number of days to 50% flowering (34.67 days) was recorded under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 35.67 days. In the present studies, the combination of PSB and Azotobacter might have further enabled the plants to produce more photosynthates and supply for the early floral primordial development which consequently led to early flower initiation and 50% flowering, Similar results were noticed in the findings of Kumar *et al.* (2022) [6] in china aster and Megha *et al.* (2022) [7] in Marigold.

Number of days to full bloom

Among soil applied bioinoculants, the minimum number of days to full bloom (38.89 days) was recorded under the treatment SD_1 (PSB @ 10%) and among foliar applied bioinoculants 38.67 days was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, minimum number of days to full bloom (36.67 days) was recorded under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 38.33 days. Earliness in number of days to 50% flowering may have positive effect on earliness in number of days to full bloom as reported by Barenya and Patra (2023) [1] in Gladiolus and Chopde *et al.* (2017) [2] in Jasmine.

Flower diameter (cm)

Among soil applied bioinoculants, the maximum flower diameter (5.58 cm) was recorded under the treatment SD_4 (Acetobacter @ 10%) and among foliar applied bioinoculants 5.64 cm was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, the maximum flower diameter (5.95 cm) was recorded under the treatment T_{14} (SD_4-Acetobacter @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 5.58 cm. Application of biofertilizers increased carbhohydrate assimilation leading to increased vegetative growth. These carbhohydrates when translocated to reproductive organs undergo hydrolysis and converted into reducing sugars which ultimately helped in increasing flower size. Similar results were reported in the findings of Yadav *et al.* (2018) [11] and Kumar and Kumar (2017) [5] in Marigold.

Table 1: Individual effect of soil and foliar applied liquid bioinoculants on flowering behaviour, yield and quality in African marigold

Treatments	Number of days to first bud initiation	Number of days to 50% flowering	Number of days to full bloom	Flower diameter (cm)	Flower yield/ hectare (qtl/ha)	Fresh weight of flowers/ plant(g)	Dry weight of flowers/ plant(g)	Flowering duration (days)	Shelf life (days)
Soil drenching(Factor A)									
(SD_0) No soil drenching	30.08^{a}	39.78^{a}	41.89^{a}	5.33^{b}	166.49^{c}	179.75^{d}	44.99^{c}	39.78^{b}	3.00
(SD_1) PSB	28.12^{b}	37^{c}	38.89^{c}	5.45^{ab}	179.76^{a}	190.74^{a}	53.16^{a}	42.78^{a}	3.22
(SD_2) ZSB	28.88^{b}	38.78^{ab}	40.78^{b}	5.35^{b}	171.81^{bc}	185.37^{c}	48.31^{b}	41.22^{ab}	3.11
(SD_3) KSB	28.31^{b}	37.67^{bc}	40^{bc}	5.43^{b}	173.62^{b}	188.45^{ab}	50.58^{b}	42.22^{a}	3.22
(SD_4) Acetobacter	28.67^{b}	38.44^{b}	40.44^{b}	5.58^{a}	172.94^{b}	186.78^{bc}	49.42^{b}	41.67^{ab}	3.33
SE(m)	0.16	0.22	0.21	0.03	1.13	0.54	0.45	0.35	
CD(5%)	0.46	0.63	0.61	0.08	3.28	1.56	1.30	1.00	NS
Foliar spray(Factor B)									
(FS_0) No foliar spray	30.03^{a}	40.33^{a}	42.47^{a}	5.21^{c}	165.69^{c}	177.57^{c}	44.28^{c}	39.4^{b}	2.6^{b}
(FS_1) Azotobacter	27.81^{b}	36.67^{c}	38.67^{c}	5.64^{a}	179.95^{a}	194.00^{a}	54.00^{a}	43.27^{a}	3.73^{a}
(FS_2) Azospirillum	28.59^{b}	38^{b}	40.07^{b}	5.44^{b}	173.12^{b}	187.07^{b}	49.59^{b}	41.93^{a}	3.2^{ab}
SE(m)	0.12	0.17	0.16	0.02	0.88	0.42	0.35	0.27	0.13
CD (5%)	0.35	0.49	0.47	0.06	2.54	1.20	1.01	0.78	0.38

Table 2: Interaction effect of soil and foliar applied liquid bioinoculants on flowering behaviour, yield and quality in African marigold

Treatment combinations	Number of days to first bud initiation	Number of days to 50% flowering	Number of days to full bloom	Flower diameter (cm)	Flower yield/ hectare (qtl/ha)	Fresh weight of flowers/ plant (g)	Dry weight of flowers/ plant (g)	Flowering duration (days)	Shelf life (days)
T_1-SD_0 (No soil drenching) + FS_0 (No foliar spray)	31.97^{a}	42.33^{a}	44.67^{a}	5.11^{e}	159.12^{h}	172.07^{k}	40.08^{j}	37.67	2.33
T_2-SD_0 (No soil drenching) + FS_1 (Azot) @ 2.5%	29.07^{bcd}	38.33^{efg}	40.33^{cd}	5.58^{b}	171.16^{defg}	184.77^{fg}	47.95^{fg}	41.00	3.67
T_3-SD_0 (No soil drenching) + FS_2 (Azos) @ 2.5%	29.2^{bc}	38.67^{def}	40.67^{c}	5.3^{cd}	169.19^{efg}	182.4^{gh}	46.93^{fgh}	40.67	3.00
T_4-SD_1 (PSB) @ 10% + FS_0 (No foliar spray)	29.37^{bc}	39^{cde}	40.67^{c}	5.26^{cde}	168.41^{efg}	180.9^{hi}	46.75^{fgh}	40.33	2.67
T_5-SD_1 (PSB) @ 10% + FS_1 (Azot) @ 2.5%	26.83^{g}	34.67^{h}	36.67^{g}	5.58^{b}	194.87^{a}	201.17^{a}	60.53^{a}	45.33	3.67
T_6-SD_1 (PSB) @ 10% + FS_2 (Azos) @ 2.5%	28.17^{e}	37.33^{g}	39.33^{def}	5.52^{b}	175.98^{bcd}	190.17^{d}	52.21^{cd}	42.67	3.33
T_7-SD_2 (ZSB) @ 10% + FS_0 (No foliar spray)	29.9^{b}	40.67^{b}	42.67^{b}	5.17^{de}	166.06^{g}	176.93^{j}	43.84^{i}	39.00	2.67
T_8-SD_2 (ZSB) @ 10% + FS_1 (Azot) @ 2.5%	28.03^{e}	37.33^{g}	39.33^{def}	5.54^{b}	176.9^{bcd}	192.89^{c}	52.7^{bcd}	43.00	3.67
T_9-SD_2 (ZSB) @ 10% + FS_2 (Azos) @ 2.5%	28.7^{cde}	38.33^{efg}	40.33^{cd}	5.35^{c}	172.46^{cdefg}	186.28^{ef}	48.39^{f}	41.67	3.00
T_{10}-SD_3 (KSB) @ 10% + FS_0 (No foliar spray)	29.43^{bc}	39.67^{bcd}	42^{b}	5.22^{cde}	167.63^{fg}	179.57^{ij}	45.53^{ghi}	40.00	2.67
T_{11}-SD_3 (KSB) @ 10% + FS_1 (Azot) @ 2.5%	27.2^{fg}	35.67^{h}	38.33^{f}	5.56^{b}	179.02^{b}	196.79^{b}	55^{b}	44.00	3.67
T_{12}-SD_3 (KSB) @ 10% + FS_2 (Azos) @ 2.5%	28.3^{de}	37.67^{fg}	39.67^{cde}	5.5^{b}	174.2^{bcde}	188.98^{de}	51.21^{de}	42.67	3.33
T_{13}-SD_4 (Aceto) @ 10% + FS_0 (No foliar spray)	29.5^{bc}	40^{bc}	42.33^{b}	5.28^{cd}	167.25^{g}	178.39^{ij}	45.18^{hi}	40.00	2.67
T_{14}-(Aceto) @ 10% + FS_1 (Azot) @ 2.5%	27.9^{ef}	37.33^{g}	38.67^{ef}	5.95^{a}	177.81^{bc}	194.4^{bc}	53.83^{bc}	43.00	4.00
T_{15} SD_4 (Aceto) @ 10% + FS_2 (Azos) @ 2.5%	28.6^{cde}	38^{efg}	40.33^{cd}	5.52^{b}	173.77^{bcdef}	187.54^{def}	49.24^{ef}	42.00	3.33
SE(m)	0.27	0.38	0.37	0.05	1.96	0.93	0.78		
CD (5%)	0.79	1.09	1.06	0.14	5.68	2.69	2.26	NS	NS

Flower yield per hectare (qtl/ha)

Among soil applied bioinoculants, the maximum flower yield per hectare (179.76 qtl/ha) was noticed under the treatment SD_1 (PSB @ 10%) and 179.95 qtl/ha was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, the maximum flower yield per hectare (194.87 qtl/ha) was noticed under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 179.02 qtl/ha. Increase in flower yield may be attributed to increased availability of phosphorus and its greater uptake by soil applied PSB and the Azotobacter helps in atmospheric nitrogen fixation, better root proliferation, uptake of nutrients and water, higher leaf number and branches. More photosynthesis enhanced food accumulation which might have resulted in increased yield as reported by Singh and Kumar (2016) [10] in Marigold and Hadwani *et al*. (2013) [4] in Tuberose.

Fresh weight of flowers per plant (g)

Among soil applied bioinoculants, the maximum average fresh weight of flowers per plant (190.74 g) was recorded under the treatment SD_1 (PSB @ 10%) and among foliar applied bioinoculants 194.00 g was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, the maximum average fresh weight of flowers per plant (201.17 g) was recorded under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 196.79 g Increase in fresh weight may be ascribed due to the effects of plant growth regulators and high rate of photosynthates from vegetative parts to the reproductive parts which subsequently might have resulted in higher fresh weight of flowers per plant as reported by Jogi *et al*. (2022) [3] in China Aster.

Dry weight of flowers per plant (g)

Among soil applied bioinoculants, the maximum average dry weight of flowers per plant (53.16 g) was recorded under the treatment SD_1 (PSB @ 10%) and among foliar applied bioinoculants 54.00 g was recorded under the treatment FS_1 (Azotobacter @ 2.5%). Among different treatment combinations, the maximum average dry weight of flowers per plant (60.53 g) was recorded under the treatment T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) followed by T_{11} (SD_3-KSB @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 55.00 g. Application of bio-fertilizers improved the nutrients availability helps in conversion of photosynthates into protein resulted on more biomass production as reported by Patil and Agasmani (2013) [9] in China Aster.

Shelf life (days)

Shelf life did not show any significant difference under the influence of different treatments. Among soil applied bioinoculants, maximum shelf life was observed in the application of soil drenching of PSB @ 10% alone (3.33 days) and 3.73 days was noticed under foliar application of Azotobacter @ 2.5% alone. Maximum number of days to 1st picking was observed in treatment combination of T_{14} (SD_4-

Acetobacter @ 10% + FS_1-Azotobacter @ 2.5%) i.e. 4.00 days.

Conclusion

Soil drenching of PSB @ 10% alone and foliar application of Azotobacter @ 2.5% alone and treatment combination T_5 (SD_1-PSB @ 10% + FS_1-Azotobacter @ 2.5%) were found to be best for flowering behaviour, yield and quality in African Marigold.

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