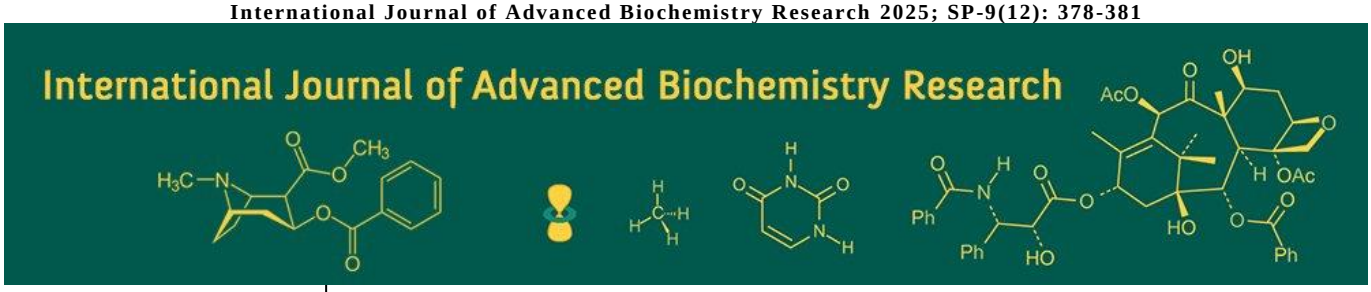

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Studies on the effect of cycocel and bio-fertilizers on the vegetative growth, flowering attributes and flower yield of calendula (*Calendula officinails* L)

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Abstract
The present study was carried out to find out the "Studies on the effect of cycocel and bio-fertilizers on the vegetative growth, flowering attributes and flower yield of calendula (*Calendula officinails* L.)" during Rabi season 2023-24 at research field of Horticulture Farm in Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment was laid out in Completely Randomized Design (CRD) with three replications. There was 15 treatments i.e. T_0 Control (water spray), T_1 CCC @ 500 ppm, T_2 CCC @ 750 ppm, T_3 CCC @ 1000 ppm, T_4 CCC @ 1500 ppm, T_5 *Azotobacter + PSB* (root dipping), T_6 *Azospirillum + PSB* (root dipping), T_7 *Azotobacter + PSB* followed by CCC @ 500 ppm, T_8 *Azospirillum + PSB* followed by CCC @ 500 ppm, T_9 Azotobacter +PSB followed by CCC @ 750 ppm, T_{10} *Azospirillum + PSB* followed by CCC @ 750 ppm, T_{11} *Azotobacter + PSB* followed by CCC @ 1000 ppm, T_{12} *Azospirillum + PSB* followed by CCC @ 1000 ppm, T_{13} *Azotobacter + PSB* followed by CCC @ 1500 ppm, T_{14} *Azospirillum + PSB* followed by CCC @ 1500 ppm. The results of study revealed that the plant treated root dipping with Azotobacter + *PSB* followed by foliar CCC @ 1500 ppm (T_{13}) that *i.e.* appropriate for improving the most parameters such as, number of branches, plant spread, stem diameter, flower longevity, delaying flowering duration, number of flower plant^{-1}, flower yield plant^{-1}. Whereas treatment *Azotobacter + PSB* (T_5) resulted increasing plant height, early bud appearance, early full bloom of flower, minimum days taken for 50% flowering, maximum average weight of flower, maximum flower diameter, maximum length of longest root, maximum fresh weight of root and maximum dry weight of roots. While, treatment CCC @ 1500 ppm (T_4) gave significantly minimum plant height and length of shortest root.

Keywords: Calendula, Cycocel, *Azotobacter*, *PSB*, *Azospirillum.*

Introduction
Floriculture is the fastest growing branch of the world agricultural sector in terms of foreign trade, especially in recent years. Today, floriculture is seen as a lucrative business with higher returns than most field and some garden crops. The development of the country is the cultivation of various flowers for the domestic and foreign markets. Even though we have modern technology, we still need to create a strong and viable foundation for the floriculture industry in India and abroad. Calendula (*Calendula officinalis* L.) is one of the cultivated seasonal flowers, belongs to Asteraceae family. It is a tetraploid plant with 32 chromosomes (2n=4x=32) (Nora *et al.*, 2013) [9]. The plants can be used in the home garden and in landscaping. It is one of the best plants for rock gardens, borders, flower beds and balcony plantings (Golestani *et al.*, 2013) [3]. Calendula was known as "gold's" in old English was associated with Virgin Mary and Queen Mary, hence the name marigold (Grieve 1931) [4]. The name of this plant comes from a Latin word 'Calend' meaning the first day of each month, because of the long flowering period of plant. As flowers move in the direction of the sun's radiation, it has become an astronomical sun sign "Leo" (Dinda and Craker, 1998) [1]. Sachs *et al*. (1960) [12] reported that application of CCC retarded stem elongation by preventing cell division in the sub-apical meristem, usually without similarly affecting the apical meristem. CCC enforce stop the vertical growth consequently induces the lateral or horizontal growth. It is very important for establishing source and sink relationship, which could be artificially induced by using PGRs for the proportionate vegetative and reproductive growth. Bio-fertilizers not only enhance nutrient uptake by plants and promote the release of growth hormones and antibiotics but also improve the quality of produce while reducing

production costs. Bio-fertilizers such as *Azotobacter* and *Azospirillum* are suitable for application in various flower crops such as rose, tuberose, carnation, marigold, and aster *etc*. *Azotobacter* converts atmospheric nitrogen into ammonia, which is then taken up and utilized by plants (Prajapati *et al*., 2010) [11]. *Azospirillum* has the ability to colonize plant roots and fix atmospheric nitrogen. The most effective method for increasing the flower yield of marigold involved the combined application of *Azotobacter* and phosphorus-solubilizing bacteria, along with 75% nitrogen (Gupta *et al*., 1999) [5].

Materials and Methods

The experiment was conducted during *Rabi* 2023-24 at research field of Horticulture Farm, Department of Floriculture and Landscape Architecture, Indira Gandhi Krishi Vishwavidyalaya,
Raipur. The experiment was laid out in Completely Randomized Design (CRD) with three replications. There was 15 treatments i.e. T_0 Control (water spray), T_1 CCC @ 500 ppm, T_2 CCC @ 750 ppm, T_3 CCC @ 1000 ppm, T_4 CCC @ 1500 ppm, T_5 *Azotobacter + PSB* (root dipping), T_6 *Azospirillum + PSB* (root dipping), T_7 *Azotobacter + PSB* followed by CCC @ 500 ppm, T_8 *Azospirillum + PSB* followed by CCC @ 500 ppm, T_9 Azotobacter +PSB followed by CCC @ 750 ppm, T_{10} *Azospirillum + PSB* followed by CCC @ 750 ppm, T_{11} *Azotobacter + PSB* followed by CCC @ 1000 ppm, T_{12} *Azospirillum + PSB* followed by CCC @ 1000 ppm, T_{13} *Azotobacter + PSB* followed by CCC @ 1500 ppm, T_{14} *Azospirillum + PSB* followed by CCC @ 1500 ppm. Biofertilizers, specifically *Azospirillum, Azotobacter, and PSB*, were applied using the root dipping method. A slurry was prepared by dissolving 5 g of jaggery in 100 ml of water and then mixing in 10 ml/liter of each biofertilizer. The roots of the seedlings were subsequently dipped in this solution for 5 minutes and CCC applied by foliar spray after 30 DAP.

Result and Discussion

vegetative parameters

Significantly tallest plant (44.62 cm) was recorded in treatment *Azotobacter + PSB* (T_5) which was *at par* with treatment *Azospirillum + PSB* (T_6) and minimum plant height (33.53) at 90 DAT was observed under CCC @ 1500 ppm (T_4). might be credited to the by applying these beneficial microorganisms to the roots, the plants were able to absorb more nutrients, leading to healthier growth and increased plant height. These results are similarly findings of Mehdi *et al.*, (2022) [8] in calendula. The maximum numberiof branches plant^{-1} (14.67), highest number of leaves plant^{-1} (231.0), plant spread was significantly greater at 90 DAT (36.99 N-S cm) and (33.63 E-W cm) and significantly maximum stem diameter (13.67 mm) noted with treatment *Azotobacter + PSB* followed by CCC @ 1500 ppm (T_{13}) which was statically similar with *Azospirillum + PSB* followed by CCC @ 1500 ppm (T_{14}) and minimum number of branches plant^{-1} (9.96) was recorded under control (T_0) shown in Table.1. The combination of *Azotobacter + PSB* treatment along with CCC application might have a synergistic effect on calendula plants. The enhanced nutrient uptake facilitated by *Azotobacter* and *PSB*, combined with the growth-regulating effects of CCC, can lead to optimal conditions for leaf development, number of branches plant^{-1}, plant spread and maximum stem diameter. These results are closely related with findings of Sahu *et al.*, (2023) [13] in annual chrysanthemum (*Chrysanthemum coronarium* L.).

Flower parameters

Minimum days to full bloom of flower (9.27 days), earliest 50% flowering (66.33 days), largest flower (5.81 cm) and highest average weight (3.55 g) were recorded under the treatment *Azotobacter + PSB* (T_5) *at0par* with *Azospirillum + PSB* (T_6) this could be due to complementary effects of *Azotobacter* and *PSB*, leading to improved flower growth and development. Also, *PSB* improved the plant's ability to resist diseases and stresses. Similar results were also reported by Mathew and Singh (2003) [7] in marigold and the significantly highest number of flower plant^{-1} (108.01), flower longevity (13.23 days), greater flowering duration (65.67 days) and flower yield ((247.67 g) were noted under the treatment *Azotobacter + PSB* followed by CCC @ 1500 ppm (T_{13}) which was *at par* with *Azospirillum + PSB* followed by CCC @ 1500 ppm (T_{14}). However, noticed minimum values were recorded under control (T_0) presented in Table. 2. Application of *Azotobacter + PSB* followed by CCC @ 1500 ppm (T_{13}). The increased flower yield, flower longevity, flowering duration, might be due to CCC which improved the root and shoot parameters, influenced secondary metabolic activities in treated plants for production and optimize flowering synchronization. It also potentially enhances stress management and pollination efficiency. Collectively, these effects result in a higher and more effective flower yield per plant. The results obtained in this investigation are in close agreement with the findings of Sikarwar and Vikram (2017) [14] in African marigold cv. Pusa Narangi Gainda. Also, *Azotobacter and PSB* affecting nutrient uptake and availability which influence flowering. Similar results were also obtained with the findings of Kumar *et al*., (2019) [6] in Dahlia.

Root parameters

The longest root (34.86 cm), maximum fresh (15.85 g) and dry weight (6.19 g) were recorded in the treatment *Azotobacter + PSB* (T_5) and recorded *at par* with treatment *Azospirillum + PSB* (T_6) and minimum values for these parameters were observed under the Control (T_0). Might be due to *Azotobacter* converts atmospheric nitrogen into a form usable by the plant, promoting healthy root growth, *PSB* makes phosphorus more available to the plant, essential for root development and growth. These results are in close agreement with the results observed by Gayatri *et al*., (2021) [2] in wheat. The significantly shortest root was recorded in the treatment CCC @ 1500 ppm (2.52 cm) T_4 and maximum (3.56 cm) was observed under the treatment *Azotobacter + PSB* (T_5) shown in Table. 3

Table 1: Effect of cycocel and bio-fertilizers on plant height, number of branches plant^{-1}, number of leaves plant^{-1}, plant spread (cm), basal stem diameter (mm) of calendula (*Calendula officinails* L.*)*

Notation	Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Plant spread (cm)		Stem diameter (mm)
					N-S	E-W	
T_0	Control (water spray)	38.70	9.96	192.33	28.46	25.87	9.82
T_1	CCC @ 500 ppm	34.76	11.47	208.69	28.85	26.22	10.56
T_2	CCC @ 750 ppm	34.53	11.73	212.64	31.13	28.30	10.95
T_3	CCC @ 1000 ppm	33.94	12.19	216.04	32.54	29.58	11.37
T_4	CCC @ 1500 ppm	33.53	13.20	220.41	34.37	31.24	11.59
T_5	*Azotobacter + PSB* (root dipping)	44.62	10.27	196.23	29.22	26.56	11.82
T_6	*Azospirillum + PSB* (root dipping)	42.79	10.07	194.49	29.34	26.67	11.62
T_7	*Azotobacter + PSB* followed by CCC @ 500 ppm	36.71	12.69	215.80	30.75	27.96	12.36
T_8	*Azospirillum + PSB* followed by CCC @ 500 ppm	36.64	12.49	216.60	30.29	27.53	12.34
T_9	*Azotobacter + PSB* followed by CCC @ 750 ppm	36.04	12.71	222.08	32.50	29.55	12.59
T_{10}	*Azospirillum + PSB* followed by CCC @ 750 ppm	35.56	12.66	219.27	32.33	29.39	12.55
T_{11}	*Azotobacter + PSB* followed by CCC @ 1000 ppm	35.18	13.42	245.67	34.30	31.18	12.71
T_{12}	*Azospirillum + PSB* followed by CCC @ 1000 ppm	35.03	13.55	223.33	33.59	30.54	12.60
T_{13}	*Azotobacter + PSB* followed by CCC @ 1500 ppm	34.97	14.67	231.04	36.99	33.63	13.67
T_{14}	*Azospirillum + PSB* followed by CCC @ 1500 ppm	34.29	14.20	227.10	35.27	32.07	13.24
SEM±		0.64	0.38	2.03	0.77	0.70	0.27
CD $_{at\ 5\%}$		1.85	1.08	5.86	2.22	2.02	0.77

Table 2: Effect of cycocel and bio-fertilizers days taken to full bloom of flower, days taken for 50% flowering, flower diameter (cm), average weight of flower (g), number of flowers plant^{-1}, flower longevity (days), flowering duration (days), flowers yield plant^{-1} (g).

Notation	Treatments	Days taken to full bloom of flower	Days taken for 50% flowering	Flowering, flower diameter (cm)	Average weight of flower (g)	Number of flowers plant^{-1}	Flower longevity (days)	Flowering duration (days)	Flowers yield plant^{-1} (g)
T_0	Control (water spray)	9.66	66.67	3.74	1.76	63.51	7.40	51.93	132.12
T_1	CCC @ 500 ppm	10.80	68.77	4.69	2.32	75.51	9.21	55.67	155.96
T_2	CCC @ 750 ppm	10.93	70.41	4.54	2.20	77.27	9.40	57.04	157.23
T_3	CCC @ 1000 ppm	11.57	71.00	4.48	2.40	84.56	9.82	58.67	185.12
T_4	CCC @ 1500 ppm	11.88	72.67	4.45	2.21	93.93	10.80	60.83	192.43
T_5	*Azotobacter + PSB* (root dipping)	9.27	63.41	5.81	3.55	68.44	8.07	55.60	152.00
T_6	*Azospirillum + PSB* (root dipping)	9.40	64.33	5.59	3.23	72.20	8.13	54.67	154.76
T_7	*Azotobacter + PSB* followed by CCC @ 500 ppm	11.28	70.45	4.87	2.44	78.91	9.88	58.30	170.88
T_8	*Azospirillum + PSB* followed by CCC @ 500 ppm	11.40	70.85	4.92	2.53	78.15	9.82	57.73	174.03
T_9	*Azotobacter + PSB* followed by CCC @ 750 ppm	11.80	72.74	4.67	2.45	83.07	10.53	61.07	199.39
T_{10}	*Azospirillum + PSB* followed by CCC @ 750 ppm	11.72	72.45	4.56	2.45	79.67	10.40	60.67	191.20
T_{11}	*Azotobacter + PSB* followed by CCC @ 1000 ppm	12.53	73.41	4.52	2.41	95.00	11.90	63.40	234.40
T_{12}	*Azospirillum + PSB* followed by CCC @ 1000 ppm	12.40	73.35	4.47	2.44	94.59	11.47	62.20	215.57
T_{13}	*Azotobacter + PSB* followed by CCC @ 1500 ppm	13.30	75.00	5.14	2.75	108.01	13.23	65.67	247.67
T_{14}	*Azospirillum + PSB* followed by CCC @ 1500 ppm	12.93	74.33	4.85	2.66	101.93	12.80	64.33	237.33
SEM±		0.34	0.77	0.18	0.09	2.18	0.32	1.15	8.28
CD $_{at\ 5\%}$		0.98	2.24	0.52	0.26	6.28	0.93	3.32	23.92

Table 3: Effect of cycocel and bio-fertilizers on length of longest root (cm), length of shortest root (cm), fresh weight of roots (g), dry weight of roots (g), of calendula (*Calendula officinails* L.)

Notation	Treatments	Length of longest root (cm)	Length of shortest root (cm)	Fresh weight of roots (g)	Dry weight of roots (g)
T_0	Control (water spray)	30.23	2.98	10.71	4.17
T_1	CCC @ 500 ppm	26.94	2.87	12.25	4.99
T_2	CCC @ 750 ppm	26.97	2.81	12.26	5.00
T_3	CCC @ 1000 ppm	26.51	2.76	12.05	4.67
T_4	CCC @ 1500 ppm	26.20	2.52	11.91	4.65
T_5	*Azotobacter + PSB* (root dipping)	34.86	3.56	15.85	6.19
T_6	*Azospirillum + PSB* (root dipping)	33.43	3.41	15.20	6.00
T_7	*Azotobacter + PSB* followed by CCC @ 500 ppm	28.68	2.93	13.04	5.27
T_8	*Azospirillum + PSB* followed by CCC @ 500 ppm	28.62	2.92	13.01	5.13
T_9	*Azotobacter + PSB* followed by CCC @ 750 ppm	28.16	2.87	12.80	5.10
T_{10}	*Azospirillum + PSB* followed by CCC @ 750 ppm	27.78	2.83	12.63	4.67
T_{11}	*Azotobacter + PSB* followed by CCC @ 1000 ppm	27.49	2.80	12.49	4.57
T_{12}	*Azospirillum + PSB* followed by CCC @ 1000 ppm	27.37	2.79	12.44	4.70
T_{13}	*Azotobacter + PSB* followed by CCC @ 1500 ppm	27.32	2.79	12.42	4.77
T_{14}	*Azospirillum + PSB* followed by CCC @ 1500 ppm	26.79	2.73	12.18	4.58
SEM±		0.50	0.14	0.24	0.21
CD $_{at\ 5\%}$		1.45	0.40	0.71	0.61

Conclusion

On the basis of the experimental findings may be concluded that the plant treated root dipping with *Azotobacter + PSB* followed by foliar CCC @ 1500 ppm (T_{13}) that i.e. appropriate for improving the most parameters such as, number of branches, plant spread, stem diameter, flower longevity, delaying flowering duration, number of flower plant^{-1}, flower yield plant^{-1}. Whereas treatment *Azotobacter + iPSB* (T_5) resulted increasing plant height, early bud appearance, early full bloom of flower, minimum days taken for 50% flowering, maximum average weight of flower, maximum flower diameter, maximum length of longest root, maximum fresh weight of root and maximum dry weight of roots. While, treatment CCC @ 1500 ppm (T_4) gave significantly minimum plant height and shortest root.

Author Contributions

Dr. S. K. Tamrakar, Major advisor of the thesis research work carried out; Pushparaj, Student who carried out this masters' thesis research work.

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