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Original Research Paper

Effects of cold stress and melioration on survival and growth winter marigold (*Tagetes erecta* L.)

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ABSTRACT

The current study examined the impact of cold stress on marigold. The genotype Pusa Bahar during winter cultivation and its melioration using elicitors, and plastic tunnels at various sowing dates. Comparing low plastic tunnels to open field settings, the results demonstrated a considerable gain in plant height (72.08 cm), dry matter accumulation (74.84 g), single flower weight (8.92 g), as well as yield (390.59 g), among other survival, growth, and blooming indices. Furthermore, it was discovered that the best time to sow marigold plants was October 15th. This was demonstrated by the plants' height (69.49 cm), dry matter accumulation (71.68 g), single flower weight (8.45 g), and yield (381.04 g). Along with this, marigold plants under cold stress showed significantly higher plant height (71.96 cm), dry matter accumulation (74.17 g), single flower weight (8.94 g), and yield (384.82 g) when 200 ppm of chito oligosaccharide was applied, especially when combined with arbuscular mycorrhiza. The viability of low plastic tunnels and the effectiveness of elicitors in boosting marigold plant survival, development, and production, as well as boosting plant resistance to cold stress during winter farming, are demonstrated.

Keywords: Arbuscular mycorrhiza, chito oligosaccharide, cold stress, marigold, melioration, salicylic acid

INTRODUCTION

In addition to its nematicide, cosmetic, and therapeutic qualities, marigold (*Tagetes erecta* L.) is a commercially developed decorative as well as medicinal plant that can be utilized to make garlands and flower displays. Antioxidants found in the flower's essential oil are employed in several industrial processes. Marigold thrives in mild climatic conditions but faces reduced growth and productivity in extremely cold temperatures, particularly challenging for winter cultivation in regions like Northern India. Cold stress, or low-temperature stress, poses significant harm to higher plants (Zhou et al., 2017). Plants that experience cold stress exhibit phenotypic indications, for example, wilting, decreased leaf growth, necrosis (tissue death), and chlorosis (leaf yellowing). It disrupts crucial physiological processes and severely impacts reproductive development, leading to decreased yield and compromised marketable quality of plants and flowers. Research indicates that marigold plants preferentially flower earlier in higher temperatures compared to lower temperatures (Blanchard & Runkle, 2011). Exogenous elicitors which include arbuscular mycorrhiza, salicylic acid, alongside chito oligosaccharides are important for controlling physiological as well as biochemical activities in plants, that helps for promoting greater plant growth and yield even in cold stress situations. It has been demonstrated that protected culture helps shield plants from various abiotic challenges and increases production in unfavourable circumstances. In light of this, a study was carried out to investigate how cold stress and amelioration affect marigolds grown in the winter.

MATERIALS AND METHODS

Seeds of the marigold variety Pusa Bahar were sown on raised nursery beds on three sowing dates namely, October 15th (SD_1), November 1st (SD_2), and November 15th (SD_3), and healthy seedlings were transplanted after 30 days of sowing at Centre for Protected Cultivation Technology (CPCT), ICAR-Indian Agricultural Research Institute, New Delhi during 2021 and 2023. At 20, 30, and 40 days after sowing, the plants were treated with salicylic acid (SA) and chito oligosaccharide (COS) at concentrations of

100, 200, and 300 ppm, respectively. At the time of planting, however, 10 grams of arbuscular mycorrhiza (AM) were administered to each plant. The treatments were applied as, T_0-control, T_1-SA 100 ppm, T_2-SA 200 ppm, T_3-SA 300 ppm, T_4-COS 100 ppm, T_5-COS 200 ppm, T_6-COS 300 ppm, T_7-AM, T_8-SA 100 ppm + AM, T_9-SA 200 ppm + AM, T_{10}-SA 300 ppm + AM, T_{11}-COS 100 ppm + AM, T_{12}-COS 200 ppm + AM, and T_{13}-COS 300 ppm + AM. The plants in the main field were grown in two growing conditions, that is, open field (E_1) alongside protected conditions (E_2), using a factorial randomized block design having 3 copies for 2 years (2021 to 2023). A low plastic tunnel was used to provide protected conditions to plants when temperatures are extremely cold, and it was removed when the temperature reached ambient growing conditions. Mortality, flowering variables like number of days to bud initiation, single flower weight (g), and yield factors including the number of flowers per plant, yield per plant (g), as well as aggregated over the two years, were all recorded. Growth parameters encompassed plant height (cm), plant spread (cm), stem diameter (cm), internodal length (cm) and number of primary branches, along with dry matter accumulation (g). Utilizing R software, the combined data was analyzed employing ANOVA, and the 'F' test was implemented to determine significance, with a critical difference (CD) at P=0.05.

RESULTS AND DISCUSSION

Under conditions of cold stress, the African marigold var. Pusa Bahar exhibited notable differences across different factors (Table 1 & 2; Fig. 1).

The highest mortality rate (30.04%) was recorded in plants grown in open field conditions (E_1), while, the lowest (9.11%) was recorded in plants covered with low plastic tunnels (E_2). Conversely, the highest in growth variables encompassing stem diameter (0.70 cm), plant height (72.08 cm), internodal length (5.13 cm), plant spread (57.76 cm), number of primary branches (13.36), dry matter accumulation (74.84 g), number of flowers per plant (37.28), single flower weight (8.92 g), yield per plant (390.59 g) and earliness to bud initiation (45.99 days) were recorded in plants covered with the low plastic tunnel (E_2). Plants from sowing on October 15th (SD_1) exhibited the lowest mortality (13.48%), whereas, the highest mortality (27.55%) was recorded in November 15th (SD_3). The maximum plant height (69.49 cm), plant spread (53.96 cm), stem diameter (0.68 cm), internodal length (4.92 cm), number of primary branches (12.06), dry matter accumulation (71.68 g), single flower weight (8.45 g), number of flowers per plant (35.91), moreover yield per plant (381.04 g) were in October 15th (SD_1) sowing. In contrast, the earliest bud initiation (41.91 days) occurred in plants from November 15th (SD_3) sowing. In addition, among the various treatments, the lowest mortality rate was recorded with T_{12}-COS 200 ppm + AM (14.67%), followed closely by T_{10}-SA 300 ppm + AM (15.31%). The treatment T_{12}-COS 200 ppm + AM resulted in the tallest plant height (71.96 cm), largest plant spread (55.31 cm), highest dry matter accumulation (74.17 g), single flower weight (8.94 g), maximum number of flowers per plant (39.53), yield per plant (384.82 g) as well as earliest bud initiation (44.18 days). The maximum stem diameter (0.71 cm) and internodal length (5.30 cm) were recorded for both T_{12}-COS 200 ppm + AM and T_{10}-SA 300 ppm + AM, while, highest number of primary branches (13.14) had been recorded in T_9-SA 200 ppm + AM. Interaction effect indicated that highest plant spread (62.03 cm), stem diameter (0.77 cm), number of flowers per plant (42.32) and yield per plant (429.99 g) were recorded in plants from sowing on October 15th treated with T_{12}-COS 200 ppm + AM and covered with low plastic tunnel, while, highest dry matter accumulation was gathered in plants of same sowing and growing conditions but treated with T_{13}-COS 300 ppm + AM. The maximum number of primary branches (15.02) and single flower weight (10.03 g) were recorded in plants from sowing date of November 1st with the same treatment. However, the tallest plant height (76.02 cm) and earliest bud initiation (35.19 days) were observed in plants from the sowing date of November 15th and treated with T_{10}-SA 300 ppm + AM under a low plastic tunnel.

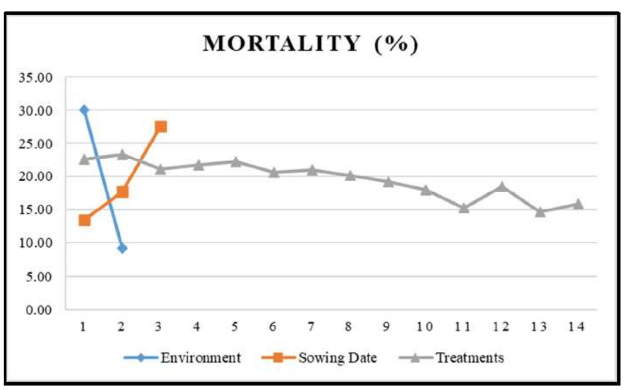

Fig. 1 : Effect of cold stress and melioration techniques on mortality percentage of marigold var. Pusa Bahar

Table 1 : Effect of cold stress and melioration techniques on vegetative parameters of marigold var. Pusa Bahar

Factor	Plant height (cm)	Plant spread (cm)	Stem diameter (cm)	Internodal length (cm)	Primary Branches (No.)
Growing condition					
Open (E_1)	64.55	47.38	0.63	4.48	10.46
Low plastic tunnel (E_2)	72.08	57.76	0.70	5.13	13.36
SEm (±)	0.11	0.07	0.00	0.01	0.02
CD (p=0.05)	0.29	0.20	0.00	0.02	0.06
Sowing date					
October 15th (SD_1)	69.49	53.96	0.68	4.92	12.06
November 1st (SD_2)	68.36	53.67	0.66	4.80	11.87
November 15th (SD_3)	67.09	50.08	0.65	4.70	11.79
SEm (±)	0.28	0.09	0.00	0.01	0.03
CD (p=0.05)	0.77	0.25	0.00	0.03	0.07
Treatment					
Control (T_0)	65.29	50.21	0.61	4.31	10.51
SA 100 ppm (T_1)	67.35	50.38	0.63	4.39	10.83
SA 200 ppm (T_2)	67.08	51.46	0.63	4.59	11.26
SA 300 ppm (T_3)	66.76	51.31	0.65	4.57	11.52
COS 100 ppm (T_4)	66.80	50.61	0.63	4.41	10.97
COS 200 ppm (T_5)	68.32	52.46	0.66	4.69	11.87
COS 300 ppm (T_6)	67.12	52.01	0.65	4.54	11.47
AM (T_7)	68.10	53.24	0.66	4.86	12.02
SA 100 ppm + AM (T_8)	68.00	53.32	0.67	4.93	12.22
SA 200 ppm + AM (T_9)	69.91	53.05	0.67	5.13	13.14
SA 300 ppm + AM (T_{10})	71.02	55.11	0.71	5.30	12.64
COS 100 ppm + AM (T_{11})	68.71	53.20	0.69	5.09	12.38
COS 200 ppm + AM (T_{12})	71.96	55.35	0.71	5.30	13.02
COS 300 ppm + AM (T_{13})	69.95	54.28	0.69	5.17	12.85
SEm (±)	0.28	0.19	0.00	0.02	0.06
CD (p=0.05)	0.77	0.53	0.01	0.06	0.15

Table 2: Effect of cold stress and melioration techniques on dry matter accumulation, flowering, and yield parameters of marigold var. Pusa Bahar

Factor	Dry matter accumulation (g)	Days to bud initiation	Single flower weight (g)	Flowers/ plant (No.)	Yield/ plant (g)
Growing condition					
Open (E_1)	66.44	50.36	7.43	33.65	334.08
Low plastic tunnel (E_2)	74.84	45.99	8.92	37.28	390.59
SEm (±)	0.12	0.08	0.01	0.05	0.58
CD (p=0.05)	0.32	0.21	0.04	0.15	1.61
Sowing date					
October 15th (SD_1)	71.68	52.67	8.45	35.91	381.04
November 1st (SD_2)	70.66	49.93	8.24	35.37	365.07
November 15th (SD_3)	69.58	41.91	7.84	35.11	340.88
SEm (±)	0.14	0.09	0.02	0.07	0.71
CD (p=0.05)	0.40	0.26	0.05	0.18	1.97
Treatment					
Control (T_0)	68.40	52.53	7.44	31.65	343.91
SA 100 ppm (T_1)	69.82	50.83	7.55	32.61	349.26
SA 200 ppm (T_2)	69.94	49.80	7.77	33.70	352.13
SA 300 ppm (T_3)	69.99	49.26	8.05	34.59	357.14
COS 100 ppm (T_4)	68.97	50.73	7.73	33.13	349.70
COS 200 ppm (T_5)	69.54	48.00	8.11	35.24	357.19
COS 300 ppm (T_6)	70.60	49.43	7.80	34.45	358.67
AM (T_7)	70.66	47.67	8.23	36.08	362.44
SA 100 ppm + AM (T_8)	69.58	47.48	8.31	36.01	365.00
SA 200 ppm + AM (T_9)	70.87	46.61	8.75	37.66	371.74
SA 300 ppm + AM (T_{10})	73.49	45.11	8.75	37.91	380.52
COS 100 ppm + AM (T_{11})	70.49	46.71	8.49	36.21	368.80
COS 200 ppm + AM (T_{12})	74.17	44.18	8.94	39.53	384.82
COS 300 ppm + AM (T_{13})	72.44	46.07	8.54	37.69	371.32
SEm (±)	0.31	0.20	0.04	0.14	1.52
CD (p=0.05)	0.85	0.56	0.10	0.40	4.26

Membrane fluidity, water potential, lipid composition, ATP supply, buildup of hazardous compounds, ion balance, and solute leakage are all adversely affected by cold stress (Theocharis et al., 2012). Additionally, it causes lesions, protoplast shrinkage, cell deformation, intracellular and intercellular ice accumulation, and ultimately cell death (Uemura et al., 1995). Plant mortality under cold stress is exacerbated by such disturbances. All facets of plant cellular activity are impacted by cold stress, which inhibits the growth of cell, root, and shoot organs (Yadav, 2010). Protected structures help to alleviate temperature fluctuations, precipitation variations, sunlight changes, and pest invasions in agriculture (Singh & Satpathy, 2005). By improving enzyme activity and photosynthesis, plastic tunnels provide the ideal environment for plant development, which eventually results in more leaves. (Soltani et al., 1995). They also elevate internal temperatures, facilitating the movement of photosynthates and promoting growth (Barthel et al., 2014). These findings align with studies on marigold (Amala et al., 2022), gladiolus (Qayyum et al., 2020), and spinach, pak choi, radish, and carrot (Shiwakoti et al., 2018). Variations in sowing dates and the associated levels of cold stress seem to directly influence development; moreover, overall progression characteristics of marigold plants. By accelerating production of phytohormones, which include auxins and gibberellins, chito oligosaccharide, a derivative of chitosan, encourages the development and progression of plants (Uthairatanakij et al., 2007). It acts as a source of amino acids, supplying vital nitrogen for growth and metabolic processes (Shibuya & Minami, 2001). It is recognized as a stimulant for plants, aiding in seed germination, growth, development, and photosynthesis, which ultimately contributes to higher productivity (Liu et al., 2023). Similar outcomes were noted in fern (Salachana et al., 2021), peanut (Shi et al., 2023), as well as in cucumber (Tan et al., 2023). Additionally, the symbiotic relationship with arbuscular mycorrhiza enhances the overall health of host plants by fostering growth and boosting productivity. It also improves photosynthesis and nutrient uptake, even under cold stress conditions (Zhu et al., 2017). According to studies on maize (Chen et al., 2014) and tomatoes (Liu et al., 2015), these results are plausible.

CONCLUSION

The experiment's results demonstrated the adverse consequences of cold stress on marigold plants as well as advantageous consequences of melioration procedures on plant development as well as survival throughout winter cultivation. Further, this study emphasizes the benefits of the low plastic tunnel and elicitors like chito oligosaccharide, salicylic acid, and arbuscular mycorrhiza in reducing yield losses and producing quality blooms for farmers even under cold stress conditions.

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