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INFLUENCE OF METABOLIC ENHANCERS AND THEIR SCHEDULE OF SPRAY ON GROWTH AND FLOWERING OF AFRICAN MARIGOLD (*Tagetes erecta* L.) CV. ARKA BHANU

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ABSTRACT

The study evaluated the influence of metabolic enhancers and their spray schedules on growth and flowering of African marigold (*Tagetes erecta* L.) cv. Arka Bhanu. The experiment was conducted in a Factorial Randomized Block Design with two replications, comprising two spray schedules, viz., 30 and 45 DAT (S_1) and 30, 45 and 60 DAT (S_2) and seven metabolic enhancer treatments. Spraying at 30, 45 and 60 DAT (S_2) significantly enhanced vegetative growth and flowering compared with S_1 . Among the metabolic enhancers, *Ascophyllum nodosum* at 2000 ppm (M_2) recorded superior plant height, stem diameter and plant spread, while protein hydrolysate at 1000 ppm (M_4) produced the maximum number of branches per plant. The interaction S_2M_2 recorded the maximum plant height (84.40 cm), stem diameter (2.29 cm) and plant spread, whereas S_2M_4 produced the highest number of branches (24.40). In respect of flowering, S_2 promoted earlier flower bud initiation, 50 per cent flowering and full bloom, besides extending flowering duration and increasing the number of pickings. Protein hydrolysate at 1000 ppm (M_4) recorded the earliest flower bud initiation (45.31 days) and 50 per cent flowering (58.03 days), while *Ascophyllum nodosum* at 2000 ppm (M_2) recorded the shortest period from bud initiation to full bloom (14.53 days), longest flowering duration and maximum number of pickings. The interaction S_2M_2 recorded the longest flowering duration (57.62 days), indicating its effectiveness in improving growth and flowering performance of African marigold.

Key words: African marigold, *Ascophyllum nodosum*, metabolic enhancers, protein hydrolysate, spray schedule, flowering.

Introduction

African marigold (*Tagetes erecta* L.), a member of the family Asteraceae, is one of approximately 50 species of the genus *Tagetes* native to Mexico, it is widely cultivated in tropical and subtropical regions and is valued commercially for its yellow to orange flowers (Kar and Patra, 2022). The crop performs well under moderate temperatures of 18 to 25°C and in fertile, well-drained loamy soils with near-neutral pH (Jaganathan *et al.*, 2023). Its flowers are rich in lutein, a carotenoid known

for its antioxidant and eye-protective properties, while flower extracts are also used in veterinary feed (Zhang *et al.*, 2020). In addition, marigold can function as a trap crop in integrated pest management owing to its production of bioactive á-terthienyl compounds with nematicidal, insecticidal, fungicidal, antiviral and cytotoxic activities (Syed Salman, 2015).

The increasing demand for quality flowers and the need for sustainable crop production have encouraged the use of metabolic enhancers in floriculture. Metabolic

enhancers are known to improve plant growth, flowering and stress tolerance through natural physiological processes. However, information on their comparative performance and optimum spray schedule in African marigold is limited. Therefore, the present investigation was undertaken to evaluate the influence of different metabolic enhancers and their spray schedules on the growth and flowering of African marigold

Seaweed extracts are increasingly recognized as sustainable agricultural inputs that enhance plant productivity and tolerance to abiotic stresses. Brown seaweeds, particularly *Laminaria japonica*, *Undaria pinnatifida*, *Ascophyllum nodosum* and *Sargassum* spp., are widely used due to their bioactive compounds, including alginates, fucoidans, laminarin and phlorotannis, which promote growth, nutrient and water uptake, and stress tolerance. Among these, *Ascophyllum nodosum* extract is widely used as a metabolic enhancer in horticultural crops to stimulate root growth and improve physiological performance (Tavares *et al.*, 2020). Further Protein hydrolysates (PHs) are plant biostimulants rich in amino acids and peptides, produced through the partial hydrolysis of plant or animal proteins (Carillo *et al.*, 2022). They enhance crop growth, productivity and quality by stimulating carbon and nitrogen metabolism, hormonal activity and nutrient uptake (Colla *et al.*, 2017). Their application has also been reported to improve nutrient and water use efficiency and increase plant tolerance to environmental stresses such as drought, salinity, temperature and nutrient deficiency (Halpern *et al.*, 2015; Colla *et al.*, 2015).

Microalgae, particularly cyanobacteria such as *Spirulina*, are recognized as sustainable biostimulants due to their rich content of proteins, amino acids, vitamins, minerals, pigments and antioxidants. Their application can enhance seed germination, plant growth, nutrient-use efficiency, flowering and yield, while improving tolerance to abiotic stresses (Colla *et al.*, 2020; Ronga *et al.*, 2019). Its bioactive compounds can improve plant growth and physiological processes, reduce dependence on chemical fertilizers and enhance mineral status and crop yield (Shaheen, 2013). In view of metabolic enhancers as sustainable inputs in increasing the production of flower crops as an ecofriendly approach, the present experiment was designed to study the influence of certain metabolic enhancers on growth and flowering of African marigold.

Materials and Methods

The field experiment was conducted during the *Rabi* season of 2025-26 at Post Graduate Institute for Horticultural Sciences, Mulugu, the experimental site comes under a semi-arid tropical climate with an altitude

of 543.3 m above mean sea level on 78.62° East longitude and 17.72° North latitude. The soil is sandy loamy in texture and the experiment was laid out in a Factorial Randomized Block Design (FRBD) with two replications, comprising fourteen treatment combinations involving two spray schedules, viz., 30 and 45 DAT (S_1) and 30, 45 and 60 DAT (S_2) and seven metabolic enhancer treatments, viz., *Ascophyllum nodosum* at 1000 and 2000 ppm, Protein hydrolysate at 500 and 1000 ppm, *Spirulina* at 1000 and 2000 ppm and an untreated control. The respective metabolic enhancer treatments were applied at the specified spray schedules, while the control treatments (T_7 and T_{14}) received no metabolic enhancer application. From each treatment and replication, five plants were randomly selected for observations. Data on plant height (cm), number of branches per plant, stem diameter (cm), plant spread (cm) (E-W) (N-S), days to flower bud initiation, days taken to 50 per cent flowering, days taken from bud initiation to full bloom, duration of flowering (days) and number of pickings. Data from the plants were averaged over two replications and analyzed using ANOVA (Panse and Sukhatme, 1985), SEM and CD at 5% level were calculated to test significance.

Results and Discussion

Growth parameters

Plant height (cm): Spray schedule significantly influenced plant height, with maximum height (78.10 cm) recorded under S_2 - Spraying at 30, 45 and 60 DAT, compared to S_1 - Spraying at 30 and 45 DAT (71.14 cm). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded the highest plant height (80.10 cm), followed by M_4 - Protein hydrolysate at 1000 ppm (77.62 cm), while the minimum (65.13 cm) was recorded in M_7 - control. The interaction effect was significant, with S_2M_2 recording the maximum plant height (84.40 cm) and S_1M_7 the minimum (64.42 cm). Spraying at 30, 45 and 60 DAT (S_2) increased plant height, probably due to sustained nutrient availability and physiological activity from the additional spray. Similar results were reported by Bharathkumar *et al.*, (2023) in African marigold. Among metabolic enhancers, *Ascophyllum nodosum* at 2000 ppm (M_2) promoted greater plant height, possibly through its bioactive compounds that enhanced nutrient uptake and vegetative growth, while protein hydrolysate also improved plant height through enhanced nutrient assimilation (Sridhar and Rengasamy, 2010).

Number of branches per plant: Spray schedule significantly influenced the number of branches per plant, with S_2 - Spraying at 30, 45 and 60 DAT recording the maximum (21.02), compared to S_1 - Spraying at 30 and 45 DAT (18.26). Among metabolic enhancers, M_4 -

Protein hydrolysate at 1000 ppm produced the highest number of branches (22.53), followed by M_2 - *Ascophyllum nodosum* at 2000 ppm (21.53), while the minimum (14.75) was recorded in M_7 - Control. The interaction effect was significant, with S_2M_4 recording the maximum number of branches (24.40), followed by S_2M_2 (23.35), which was at par, whereas S_1M_7 recorded the minimum (14.40). Spraying at 30, 45 and 60 DAT (S_2) increased the number of branches per plant, probably due to sustained nutrient availability and physiological activity from the additional foliar application, which promoted axillary bud development. Among metabolic enhancers, protein hydrolysate at 1000 ppm (M_4) recorded the highest branching, possibly owing to its amino acids and bioactive peptides that enhance nutrient uptake and cellular metabolism (Carillo *et al.*, 2022). *Ascophyllum nodosum* at 2000 ppm (M_2) also promoted branching, potentially through its bioactive compounds that support vegetative growth. Similar responses to biostimulant application were reported by Vignesh *et al.*, (2026) in African marigold.

Stem diameter (cm): Spray schedule significantly influenced stem diameter, with S_2 - Spraying at 30, 45 and 60 DAT recording the maximum diameter (2.01 cm), compared to S_1 - Spraying at 30 and 45 DAT (1.78 cm). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded the highest stem diameter (2.09 cm), followed by M_4 - Protein hydrolysate at 1000 ppm and M_6 - *Spirulina* at 2000 ppm (2.01 cm each), while the minimum (1.46 cm) was recorded in M_7 - Control. The interaction effect was significant, with S_2M_2 recording the maximum stem diameter (2.29 cm) and S_1M_7 the minimum (1.41 cm). Spraying at 30, 45 and 60 DAT (S_2) increased stem diameter, probably due to

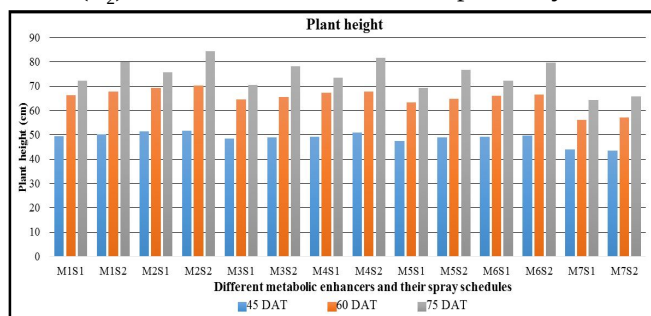


Fig. 1: Effect of metabolic enhancers and their schedule of spray on plant height (cm) at 45, 60 and 75 DAT of African marigold (*Tagetes erecta* L.) cv. Arka bhanu. S_1 - Spraying at 30 and 45 DAT; S_2 - Spraying at 30, 45 and 60 DAT; M_1 - *Ascophyllum nodosum* at 1000 ppm; M_2 - *Ascophyllum nodosum* at 2000 ppm; M_3 - Protein hydrolysate at 500 ppm; M_4 - Protein hydrolysate at 1000 ppm; M_5 - *Spirulina* at 1000 ppm; M_6 - *Spirulina* at 2000 ppm; M_7 - Control (water spray).

sustained nutrient availability and enhanced physiological activity supporting stem development. Among metabolic enhancers, *Ascophyllum nodosum* at 2000 ppm (M_2) produced the maximum stem diameter, possibly due to its bioactive compounds and micronutrients, while protein hydrolysate at 1000 ppm (M_4) also promoted stem development through improved metabolic activity (Carillo *et al.*, 2022). Similar results were reported by Rupali Thakur *et al.*, (2026) in marigold.

Plant spread (cm) (EW): Spray schedule significantly influenced plant spread (E - W), with S_2 - Spraying at 30, 45 and 60 DAT recording the maximum spread (65.92 cm), compared to S_1 - Spraying at 30 and 45 DAT (61.55 cm). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded the highest plant spread (68.12 cm), followed by M_4 - Protein hydrolysate at 1000 ppm (65.65 cm), M_1 - *Ascophyllum nodosum* at 1000 ppm (65.52 cm) and M_6 - *Spirulina* at 2000 ppm (65.12 cm), while the minimum (56.09 cm) was recorded in M_7 - Control. The interaction effect was significant, with S_2M_2 recording the maximum plant spread (70.30 cm) and S_1M_7 the minimum (55.54 cm).

Plant spread (cm) (NS): Spray schedule significantly influenced plant spread (N - S), with S_2 - Spraying at 30, 45 and 60 DAT recording the maximum spread (64.11 cm), compared to S_1 - Spraying at 30 and 45 DAT (59.79 cm). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded the highest spread (66.40 cm), followed by M_4 - Protein hydrolysate at 1000 ppm (63.80 cm), M_1 - *Ascophyllum nodosum* at 1000 ppm (63.70 cm) and M_6 - *Spirulina* at 2000 ppm (63.33 cm), while the minimum (54.32 cm) was recorded in M_7 - Control. The interaction effect was significant, with S_2M_2 recording the maximum plant spread (68.40

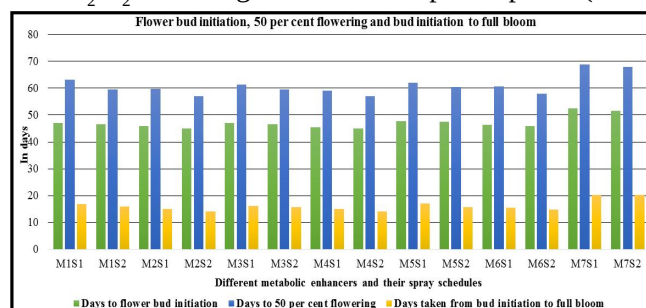


Fig. 2: Effect of metabolic enhancers and their schedule of spray on flowering parameters of African marigold (*Tagetes erecta* L.) cv. Arka bhanu. S_1 - Spraying at 30 and 45 DAT; S_2 - Spraying at 30, 45 and 60 DAT; M_1 - *Ascophyllum nodosum* at 1000 ppm; M_2 - *Ascophyllum nodosum* at 2000 ppm; M_3 - Protein hydrolysate at 500 ppm; M_4 - Protein hydrolysate at 1000 ppm; M_5 - *Spirulina* at 1000 ppm; M_6 - *Spirulina* at 2000 ppm; M_7 - Control (water spray).

Table 1: Effect of metabolic enhancers and their schedule of spray on growth and flowering parameters of African marigold (*Tagetes erecta* L.) cv. Arka bhanu.

Treatments	PH	NB	SD	PSE	PSN	DTI	DTF	DB	DF	NP
Schedule of spray										
S ₁	71.14	18.26	1.78	61.55	59.79	47.49	62.12	16.57	43.88	2.92
S ₂	78.10	21.02	2.01	65.92	64.11	46.91	59.91	15.82	53.22	3.71
S.Em±	0.29	0.13	0.01	0.22	0.20	0.15	0.37	0.13	0.27	0.05
CD @ 5%	0.89	0.40	0.04	0.67	0.61	0.47	1.15	0.39	0.84	0.15
Metabolic enhancers										
M ₁	76.14	19.05	1.90	65.52	63.70	46.83	61.39	16.42	50.20	3.50
M ₂	80.10	21.53	2.09	68.12	66.40	45.49	58.39	14.53	51.82	4.00
M ₃	74.42	19.80	1.90	63.20	61.40	46.89	60.39	15.89	49.32	3.50
M ₄	77.62	22.53	2.01	65.65	63.80	45.31	58.03	14.62	50.85	3.75
M ₅	73.01	18.96	1.90	62.45	60.72	47.67	61.24	16.46	48.86	3.00
M ₆	75.92	20.90	2.01	65.12	63.33	46.20	59.29	15.19	50.48	3.50
M ₇	65.13	14.75	1.46	56.09	54.32	52.00	68.39	20.27	38.33	2.00
S.Em±	0.54	0.25	0.02	0.41	0.37	0.29	0.70	0.24	0.51	0.09
CD @ 5%	1.66	0.76	0.07	1.26	1.14	0.89	2.15	0.74	1.57	0.28
Interaction										
T ₁ - S ₁ M ₁	72.22	17.65	1.80	63.55	61.80	47.15	63.19	16.91	44.24	3.0
T ₂ - S ₁ M ₂	75.81	19.72	1.90	65.95	64.40	46.01	59.81	14.93	46.02	4.0
T ₃ - S ₁ M ₃	70.55	18.45	1.78	60.55	58.76	47.10	61.25	16.17	44.45	3.0
T ₄ - S ₁ M ₄	73.54	20.67	1.88	63.20	61.35	45.54	59.08	15.05	45.55	3.5
T ₅ - S ₁ M ₅	69.31	17.50	1.78	59.80	58.09	47.81	62.01	17.15	43.85	2.0
T ₆ - S ₁ M ₆	72.17	19.47	1.91	62.30	60.52	46.41	60.68	15.49	44.94	3.0
T ₇ - S ₁ M ₇	64.42	14.40	1.41	55.54	53.65	52.43	68.85	20.30	38.14	2.0
T ₈ - S ₂ M ₁	80.07	20.45	2.01	67.50	65.60	46.51	59.60	15.92	56.16	4.0
T ₉ - S ₂ M ₂	84.40	23.35	2.29	70.30	68.40	44.98	56.97	14.12	57.62	4.0
T ₁₀ - S ₂ M ₃	78.28	21.15	2.02	65.85	64.05	46.68	59.53	15.61	54.19	4.0
T ₁₁ - S ₂ M ₄	81.71	24.40	2.14	68.10	66.25	45.08	56.99	14.19	56.16	4.0
T ₁₂ - S ₂ M ₅	76.71	20.42	2.02	65.10	63.35	47.53	60.47	15.77	53.86	4.0
T ₁₃ - S ₂ M ₆	79.68	22.32	2.11	67.95	66.15	46.00	57.90	14.89	56.02	4.0
T ₁₄ - S ₂ M ₇	65.84	15.10	1.50	56.65	55.00	51.58	67.94	20.25	38.52	2.0
S.Em±	0.77	0.35	0.03	0.58	0.53	0.41	0.99	0.34	0.73	0.13
CD @ 5%	2.35	1.08	0.10	1.79	1.62	NS	NS	NS	2.22	0.40
PH: Plant height (cm); NB: Number of branches; SD: Stem diameter (cm); PSE: Plant spread(E-W)(cm); PSN: Plant spread(N-S)(cm); DTI: Days taken to flower bud initiation; DTF: Days taken to 50 % flowering; DB: Days taken from bud initiation to full bloom; DF: Duration of flowering (days); NP: Number of pickings S ₁ - Spraying at 30 and 45 DAT; S ₂ - Spraying at 30, 45 and 60 DAT; M ₁ - <i>Ascophyllum nodosum</i> at 1000 ppm; M ₂ - <i>Ascophyllum nodosum</i> at 2000 ppm; M ₃ - Protein hydrolysate at 500 ppm; M ₄ - Protein hydrolysate at 1000 ppm; M ₅ - <i>Spirulina</i> at 1000 ppm; M ₆ - <i>Spirulina</i> at 2000 ppm; M ₇ - Control (water spray)										

cm) and S₁M₇ the minimum (53.65 cm). Spraying at 30, 45 and 60 DAT (S₂) increased plant spread in both E - W and N - S directions, probably due to sustained nutrient availability from the additional spray, promoting lateral growth and canopy expansion. Among metabolic enhancers, *Ascophyllum nodosum* at 2000 ppm (M₂) recorded the maximum plant spread, possibly owing to its bioactive compounds that support cell division, elongation and branch development, while protein hydrolysate also promoted canopy growth through improved metabolic activity and assimilate partitioning

(Colla *et al.*, 2017). Similar results were reported by Bharathkumar *et al.*, (2023) in Marigold and David *et al.*, (2023) in china aster.

Flowering parameters

Days taken to flower bud initiation: The schedule of spray significantly influenced days to flower bud initiation. Minimum days (46.91 days) were recorded with S₂ - Spraying at 30, 45 and 60 DAT, compared to S₁ - Spraying at 30 and 45 DAT (47.49 days). Among metabolic enhancers, M₄ - Protein hydrolysate at 1000 ppm recorded minimum days to flower bud initiation (45.31

days), which was at par with M_2 - *Ascophyllum nodosum* at 2000 ppm (45.49 days), while maximum days (52.00 days) were recorded in M_7 - Control. The interaction effect of spray schedule and metabolic enhancers was non-significant.

Days taken to 50 % flowering: The schedule of spray significantly influenced days to 50 per cent flowering. Minimum days (59.91 days) were recorded with S_2 - Spraying at 30, 45 and 60 DAT, compared to S_1 - Spraying at 30 and 45 DAT (62.12 days). Among metabolic enhancers, M_4 - Protein hydrolysate at 1000 ppm recorded minimum days to 50 per cent flowering (58.03 days), whereas M_2 - *Ascophyllum nodosum* at 2000 ppm (58.39 days) and M_6 - *Spirulina* at 2000 ppm (59.29 days), which are statistically at par, while maximum days (68.39 days) were recorded in M_7 - Control. The interaction effect of spray schedule and metabolic enhancers was non-significant.

Days taken from bud initiation to full bloom: The spray schedule significantly influenced the number of days from bud initiation to full bloom. Minimum days (15.82 days) were recorded with S_2 - Spraying at 30, 45 and 60 DAT, compared to S_1 - Spraying at 30 and 45 DAT (16.57 days). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded minimum days (14.53 days), followed by M_4 - Protein hydrolysate at 1000 ppm (14.62 days), while maximum days (20.27 days) were recorded in M_7 - Control. The interaction effect of spray schedule and metabolic enhancers was non-significant. Spraying at 30, 45 and 60 DAT (S_2) advanced flower bud initiation, 50 per cent flowering and full bloom, probably due to repeated nutrient supply during critical reproductive stages, which enhanced physiological activity and assimilate availability for floral development. Similar effects of foliar application on flowering behaviour were reported by Selvarasu *et al.*, (2022) in African marigold. Among the metabolic enhancers, protein hydrolysate at 1000 ppm (M_4) promoted earlier bud initiation and 50 per cent flowering, possibly through enhanced nitrogen metabolism and the supply of amino acids and peptides, whereas *Ascophyllum nodosum* at 2000 ppm (M_2) accelerated full bloom, which may be attributed to the bioactive compounds in seaweed extracts that influence nutrient uptake and plant physiological processes (Carillo *et al.*, 2022).

Duration of flowering: The spray schedule significantly influenced the duration of flowering. Maximum duration (53.22 days) was recorded with S_2 - Spraying at 30, 45 and 60 DAT, compared to S_1 - Spraying at 30 and 45 DAT (43.88 days). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded maximum duration of flowering (51.82 days),

and M_4 - Protein hydrolysate at 1000 ppm (50.85 days) was statistically at par, while minimum duration (38.33 days) was recorded in M_7 - Control. The interaction effect was significant, with S_2M_2 - Spraying at 30, 45 and 60 DAT + *Ascophyllum nodosum* at 2000 ppm recording the maximum duration (57.62 days), significantly superior to the other treatment combinations. It was followed by S_2M_1 and S_2M_4 (56.16 days each), while minimum duration (38.14 days) was recorded in S_1M_7 - Spraying at 30 and 45 DAT + control. Spraying at 30, 45 and 60 DAT (S_2) prolonged flowering duration, probably due to sustained nutrient availability and physiological activity during the reproductive phase. *Ascophyllum nodosum* at 2000 ppm (M_2) recorded the longest flowering duration, at par with protein hydrolysate at 1000 ppm (M_4), possibly due to their bioactive compounds enhancing nutrient-use efficiency and assimilate availability (Colla *et al.*, 2017; Shukla *et al.*, 2019). Similar results were reported by Bhargavi *et al.*, (2018) in chrysanthemum.

Number of pickings: The spray schedule significantly influenced the number of pickings. Maximum number of pickings (3.71) was recorded with S_2 - Spraying at 30, 45 and 60 DAT, compared to S_1 - Spraying at 30 and 45 DAT (2.92). Among metabolic enhancers, M_2 - *Ascophyllum nodosum* at 2000 ppm recorded maximum pickings (4.00), which was at par with M_4 - Protein hydrolysate at 1000 ppm (3.75), while minimum pickings (2.00) were recorded in M_7 - Control. The interaction effect was significant, with S_2 treatments recording the maximum number of pickings (4.00), whereas minimum pickings (2.00) were recorded in S_1M_5 - Spraying at 30 and 45 DAT + *Spirulina* at 1000 ppm and S_1M_7 - Spraying at 30 and 45 DAT + control. Spraying at 30, 45 and 60 DAT (S_2) increased the number of pickings, probably due to sustained nutrient availability and prolonged flowering, which supported continuous flower production during the reproductive phase. Similar findings were reported by Rashed *et al.*, (2025) in African marigold.

Conclusion

The study revealed that foliar application of metabolic enhancers and spray schedules significantly influenced the growth and flowering of African marigold cv. Arka Bhanu. Three sprays at 30, 45 and 60 DAT (S_2) consistently enhanced plant growth and promoted earlier flowering compared with S_1 . Among the metabolic enhancers, *Ascophyllum nodosum* at 2000 ppm (M_2) was most effective in improving vegetative growth, including plant height, stem diameter and plant spread, while protein hydrolysate at 1000 ppm (M_4) also performed well. The interaction S_2M_2 - three sprays at 30, 45 and 60 DAT + *Ascophyllum nodosum* at 2000

ppm was the most effective combination for growth and flowering performance.

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