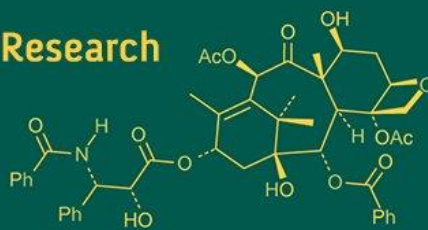


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Optimization of seaweed extract application and irrigation intervals for enhanced economic returns in marigold

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Abstract

The economic evaluation of crop-management practices is crucial for determining whether the additional expenditure on production inputs is adequately offset by the returns from the crop. This study aimed to assess the economic performance of seaweed extract application under varying irrigation intervals in marigold cultivation. The experiment was structured using a Factorial Completely Randomized Design, incorporating four levels of seaweed extract: tap water (A_1), 3 ml (A_2), 5 ml (A_3), and 7 ml (A_4). These were combined with three irrigation schedules: daily irrigation (B_1), irrigation at three-day intervals (B_2), and irrigation at six-day intervals (B_3), resulting in 12 treatment combinations with three replications each. Economic performance was evaluated based on total cost, gross return, net return, and benefit:cost ratio over a two-year period. Significant differences in profitability were observed among the treatment combinations. On a pooled basis, T_{11} (A_4B_2 : 7 ml seaweed extract + three-day irrigation interval) was the most profitable treatment, achieving the highest gross return (₹235.095/30 pots), net return (₹65.025/30 pots), and benefit:cost ratio (1.385) against a total cost of ₹170.07/30 pots. T_8 and T_5 followed, with pooled benefit:cost ratios of 1.255 and 1.210, respectively. Conversely, T_{12} exhibited the lowest economic performance, with a net return of -₹75.715/30 pots and a benefit:cost ratio of 0.555. The results indicate that increased expenditure on inputs was economically justified only when it led to a substantial improvement in monetary returns. Under the experimental conditions, the application of 7 ml seaweed extract combined with irrigation at three-day intervals proved to be the most economically beneficial treatment for marigold production.

Keywords: Marigold, seaweed extract, irrigation interval, economic evaluation, net return, benefit:cost ratio

Introduction

A production practice becomes meaningful to a grower only when the biological advantage it offers is large enough to recover the money spent to achieve it. In marigold cultivation, higher flower production may not always translate into greater profitability, particularly when additional inputs, such as biostimulants and frequent irrigation, increase the cost of production. The economic merit of a treatment is ultimately determined by the balance between the expenditure incurred and the monetary value of flowers produced. Studies on marigold economics have also shown that profitability is shaped by production costs and the returns realized from flower yield, making economic assessment an important component of treatment evaluation (Miah and Rashid, 2012; Raj *et al.*, 2022) [2, 11].

Irrigation serves as both a physiological necessity for crops and a regular input in production. Modifying the time intervals between irrigation sessions can affect plant growth and alter the resources needed, such as water, labor, and management, during the growing process. Consequently, increasing the frequency of irrigation may not always be the most cost-effective strategy if the extra costs do not lead to a corresponding rise in flower yield. Research on the economics of marigold cultivation has highlighted irrigation as a factor in production costs, underscoring the importance of evaluating water management from both a productivity and financial standpoint (Miah and Rashid, 2012) [2]. Seaweed extracts introduce an economic dimension to crop management. These products are increasingly used as plant biostimulants because seaweed-derived compounds can support

plant growth, nutrient acquisition, and tolerance to environmental stress (Tejasree *et al.*, 2024) ^[15]. Nevertheless, increasing the concentration of seaweed extract also increases the variable cost of cultivation. A treatment producing a favorable biological response may consequently be less attractive economically when the additional return does not compensate for its higher input cost. This makes economic evaluation particularly relevant when different concentrations of seaweed extract are tested, rather than assuming that the treatment producing the strongest growth response will automatically provide the greatest profit.

The simultaneous management of seaweed extract and irrigation intervals presents an important economic trade-off. Their combinations can differ not only in their influence on flower production but also in the expenditure required to obtain that production. Gross return alone cannot adequately describe this relationship because a treatment that generates greater revenue may also involve substantially higher costs. Measures such as net return and benefit:cost ratio provide a clearer indication of whether the additional investment is financially worthwhile. Treatment-based economic analyses of African marigold have demonstrated appreciable differences in gross return, net return, and benefit:cost ratio among production practices, highlighting the importance of profitability alongside biological performance (Markam *et al.*, 2020) ^[8]. Cost-and-return analysis has also been used to assess the economic feasibility of marigold production in India (Tigga *et al.*, 2023) ^[16].

Although there is growing interest in seaweed-based biostimulants, their economic performance concerning irrigation frequency has been relatively understudied in marigolds. This information is crucial, as an economically efficient treatment should yield adequate financial returns without excessive input use. Therefore, assessing individual treatment combinations can identify not only the most profitable option but also those where additional expenditure does not result in sufficient returns.

Therefore, the present investigation was undertaken to assess the economic performance of different levels of seaweed extract in combination with varying irrigation intervals in marigold through total cost, gross return, net return, and benefit:cost ratio, and to identify the treatment combination offering the greatest economic advantage under the experimental conditions.

Materials and Methods

Experimental Details

The investigation was conducted during 2024-25 and 2025-26 at the Floriculture farm of the Department of Floriculture and Landscaping, Mahatma Gandhi Udyaniki Evam Vaniki Vishwavidyalaya, Durg, Chhattisgarh, India. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications. Four levels of seaweed extract, namely A₁-tap water (control), A₂-3 ml, A₃-5 ml, and A₄-7 ml, were combined with three irrigation intervals, viz., B₁-daily irrigation, B₂-irrigation at three-day interval, and B₃-irrigation at six-day interval, resulting in 12 treatment combinations.

Table 1: Treatment combinations of seaweed extract and irrigation intervals in marigold

Treatment	Combination	Treatment details (Seaweed extract + Irrigation interval)
T ₁	A ₁ B ₁	Tap water (control) + Daily irrigation
T ₂	A ₁ B ₂	Tap water (control) + Three-day irrigation interval
T ₃	A ₁ B ₃	Tap water (control) + Six-day irrigation interval
T ₄	A ₂ B ₁	3 ml seaweed extract + Daily irrigation
T ₅	A ₂ B ₂	3 ml seaweed extract + Three-day irrigation interval
T ₆	A ₂ B ₃	3 ml seaweed extract + Six-day irrigation interval
T ₇	A ₃ B ₁	5 ml seaweed extract + Daily irrigation
T ₈	A ₃ B ₂	5 ml seaweed extract + Three-day irrigation interval
T ₉	A ₃ B ₃	5 ml seaweed extract + Six-day irrigation interval
T ₁₀	A ₄ B ₁	7 ml seaweed extract + Daily irrigation
T ₁₁	A ₄ B ₂	7 ml seaweed extract + Three-day irrigation interval
T ₁₂	A ₄ B ₃	7 ml seaweed extract + Six-day irrigation interval

Economic Analysis

The economic performance of different treatment combinations was evaluated in terms of the total cost of cultivation, gross return, net return, and benefit:cost (B:C) ratio. The overall expenditure on experimental inputs was calculated for 360 pots, whereas treatment-wise economic returns were expressed based on 30 pots. Calculations were made separately for 2024-25 and 2025-26, followed by pooled estimates for a comparison of treatment performance.

Total Cost of Cultivation

The total cost of cultivation represents the aggregate expenditure incurred on all inputs and operations required for crop production under a particular treatment.

Total Cost of Cultivation (₹) = ∑Cost of all production inputs and operations

Gross Return

Marketable marigold flowers obtained from each treatment were categorized into Grade A, Grade B and Grade C. The quantity of flowers under each grade was valued at its respective prevailing market price per kilogram, and the values of all grades were summed to determine the gross returns.

Gross return (₹/30 pots) = ∑ [Quantity of flowers in each grade (kg) × respective market price (₹/kg)]

Net Return and B:C Ratio

Net return was determined by deducting the total cost of cultivation from the gross return obtained for each treatment.

Net return (₹/30 pots) = Gross return – Total cost

The relative economic efficiency of the treatments was assessed using the benefit:cost ratio as follows:

B:C ratio = Gross return/Total cost

Year-wise economic values were calculated separately, and their mean was used to obtain pooled economic estimates for the two experimental years.

Results and Discussion

The economic response of marigold differed appreciably among the combinations of seaweed extract and irrigation intervals during the 2024-25 and 2025-26. Variations in treatment expenditure and the monetary value of flower production resulted in distinct differences in gross and net returns. The findings indicate that economic superiority was not governed by lower production costs alone; rather, profitability depended on the ability of a treatment to generate sufficient additional returns to compensate for the expenditure incurred. Such differences in production costs and profitability are commonly encountered in commercial marigold cultivation and have been reported under different production situations in India (Raut, 2021; Kumar and Malik, 2024) [12, 5].

Cost of Cultivation

The total cost of cultivation varied from ₹119.67 to ₹170.07 per 30 pots across the treatment combinations. The lowest cost of ₹119.67 was recorded under T₁, T₂, and T₃, which used tap water without the addition of seaweed extract. As seaweed extract levels increased, treatment costs rose to ₹141.27 under T₄-T₆ and ₹155.67 under T₇-T₉, while the highest cost of ₹170.07 per 30 pots was incurred under T₁₀, T₁₁, and T₁₂, which received 7 ml seaweed extract.

The progressive increase in cost was primarily associated with the additional expenditure incurred by the seaweed extract. Nevertheless, treatments with identical costs did not produce comparable economic outcomes. This was particularly evident among T₁₀, T₁₁, and T₁₂, which incurred the same total expenditure but differed substantially in their monetary returns because the seaweed treatment was combined with different irrigation intervals. This indicates that the economic value of an additional production input depends on the crop response generated under accompanying management conditions. Variation in cultivation costs and returns according to input use has also been documented in marigold production systems by Gupta *et al.* (2023) [1], while Kumar and Malik (2024) [5] emphasized the importance of efficient allocation of production resources in determining economic returns from marigold cultivation.

Table 2: Cost of cultivation for 360 pots of marigold

Particulars	Total cost (₹)
Pots	720.00
Seedlings	216.00
Seaweed extract	324.00
Miscellaneous expenses	500.00
Total cost of cultivation	1,760.00

Gross Return

The gross return showed pronounced variation among the treatment combinations in both experimental years. During 2024-25, T₁₁ (A₄B₂: 7 ml seaweed extract + irrigation at three-day intervals) recorded the highest gross return of ₹216.99 per 30 pots. Its superiority was maintained during 2025-26, when the gross return increased to ₹253.20 per 30

pots. Consequently, T₁₁ registered the maximum pooled gross return of ₹235.095 per 30 pots.

The next highest pooled gross returns were obtained under T₁₀ (₹199.935) and T₈ (₹195.690). In contrast, the minimum pooled gross return was recorded under T₃ (₹84.445). Relatively low pooled gross returns were also obtained under T₆ (₹85.155), T₉ (₹90.195), and T₁₂ (₹94.355). A notable pattern was observed under the six-day irrigation interval, where low monetary returns occurred across different seaweed extract levels.

The superior gross return under T₁₁ can be attributed to the favorable crop response obtained when the higher seaweed extract level was accompanied by a moderate irrigation interval. Seaweed-derived biostimulants can modify plant responses to water limitation by altering physiological and biochemical processes. In African marigold, Shahverdi *et al.* (2026) [13] demonstrated that seaweed extract alleviated several adverse responses associated with drought stress, including reductions in biomass and photosynthetic pigments, while enhancing mechanisms involved in stress adjustment. These responses provide physiological support for the hypothesis that seaweed supplementation can improve crop performance under an appropriate water regime.

The importance of irrigation scheduling in determining the productive and economic responses of marigold has also been supported by previous studies. Machnoor *et al.* (2023) [7] observed considerable differences in water-use efficiency and B:C ratio of marigold under different irrigation regimes, demonstrating that irrigation management can influence both resource-use efficiency and economic outcome. Recently, regulated deficit irrigation in marigolds was reported to improve crop performance and economic returns when combined with appropriate nutrient management (Kumar *et al.*, 2026) [10]. Thus, the superior gross return obtained under T₁₁ in the present investigation appears to reflect a favorable balance between seaweed supplementation and irrigation frequency rather than the effect of increased seaweed input alone.

This interpretation is further supported by the contrasting performances of T₁₁ and T₁₂. Both treatments received 7 ml seaweed extract and incurred the same total cost of ₹170.07 per 30 pots; however, their pooled gross returns were ₹235.095 and ₹94.355, respectively. The large difference between these treatments indicates that increasing expenditure on seaweed extract could not maintain monetary returns when combined with the prolonged six-day irrigation interval.

Net Return

Net return provides a more direct assessment of treatment profitability by accounting for the expenditure incurred in generating gross returns. T₁₁ recorded the highest net return during both years, amounting to ₹46.92 per 30 pots in 2024-25 and ₹83.13 per 30 pots in 2025-26. Accordingly, the pooled net return reached ₹65.025 per 30 pots, which was the highest among all treatment combinations.

The next highest pooled net return was obtained under T₈ (₹40.020), followed by T₁₀ (₹29.865), and T₅ (₹29.775). Although T₁₁ incurred the highest category of production expenditure, the additional cost was adequately compensated for by the greater monetary value of flower production. Therefore, this treatment generated the greatest economic surplus. Similar relationships between improved

flower productivity and greater economic returns have been observed in the African marigold. Markam *et al.*, (2020) [8], for example, reported that the treatment producing superior flower yield also generated the highest gross and net returns under the Chhattisgarh plains. Kaur *et al.*, (2020) [4] likewise reported that improved marigold production technology enhanced yield together with gross and net monetary returns compared with farmers' conventional practices.

In contrast, negative pooled net returns were recorded under T₃ (₹-35.225), T₄ (₹-7.435), T₆ (₹-56.115), T₉ (₹-65.475), and T₁₂ (₹-75.715). Among these treatments, T₁₂ resulted in the greatest economic loss. A negative net return indicates that the gross income generated by a treatment was insufficient to recover its corresponding cultivation costs. Therefore, these negative values represent economically unfavorable treatment responses rather than computational anomalies. The progressive economic disadvantage observed under several six-day irrigation treatments deserves particular consideration. At the 3, 5 and 7 ml seaweed levels, treatments T₆, T₉ and T₁₂ all extract was unable to compensate for the lower monetary output associated with the prolonged produced negative pooled net returns for the entire sample. This pattern suggests that additional investment is needed in seaweed irrigation intervals. Conversely, combining the same seaweed levels with the three-day irrigation interval resulted in positive pooled net returns under T₅, T₈, and T₁₁. This comparison demonstrated that the profitability of seaweed application was strongly dependent on the accompanying irrigation schedule.

The economic advantage associated with improved crop productivity is consistent with the findings of Shukla *et al.* (2026) [14], who reported that an integrated nutrient-management treatment producing the highest flower yield in African marigold also generated the highest gross and net returns. Prakash *et al.* (2026) [10] similarly observed that improved productivity under integrated nutrient management translated into superior economic returns in African marigold. Collectively, these studies support the principle observed in the present investigation that additional input expenditure becomes economically

meaningful only when it produces a sufficiently large improvement in marketable-flower output.

Economic Efficiency of Treatment Combinations

The overall economic response clearly distinguished T₁₁ (A₄B₂: 7 ml seaweed extract + three-day irrigation interval) as the most remunerative treatment combination. Its economic superiority was particularly noteworthy because it did not arise from minimizing the cultivation expenditure. Instead, the treatment belonged to the highest cost category but generated sufficient additional gross returns to produce the greatest net monetary gain.

This relationship demonstrates that the selection of an economically suitable production practice should not be based exclusively on the magnitude of input expenditure. A comparatively expensive treatment may remain financially advantageous when its improvement in marketable yield and monetary return exceeds the additional expenditure. Conversely, a high-cost treatment becomes economically undesirable when the corresponding crop response is insufficient. Similar variations in economic efficiency among marigold production practices have been reported by Raj *et al.* (2022) [11], who observed substantial differences in net benefits and B:C ratios among different growing systems. Raut (2021) [12] also demonstrated that profitability in commercial marigold production depends on the relationship between cultivation expenditure and monetary return, rather than production cost considered in isolation.

The findings of the present investigation further revealed a clear interaction between input intensity and irrigation management from an economic perspective. At each seaweed extract level, the three-day irrigation interval produced a more favorable economic outcome than the corresponding six-day interval. Most importantly, increasing the seaweed extract from the control to 7 ml under the three-day irrigation schedule progressively improved the pooled economic outcome, culminating in the highest gross and net returns under T₁₁. In contrast, increasing seaweed input at the six-day interval failed to recover the additional expenditure and resulted in economic losses.

Table 3: Economics of seaweed extract and irrigation interval treatments in marigold

Treatment	Cost (₹/30 pots)	Gross Return (₹/30 pots)			Net Return (₹/30 pots)			B:C Ratio		
		2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
T ₁	119.67	121.99	139.58	130.785	2.32	19.91	11.115	1.02	1.17	1.095
T ₂	119.67	114.72	125.83	120.275	-4.95	6.16	0.605	0.96	1.05	1.005
T ₃	119.67	83.92	84.97	84.445	-35.75	-34.70	-35.225	0.70	0.71	0.705
T ₄	141.27	127.92	139.75	133.835	-13.35	-1.52	-7.435	0.91	0.99	0.950
T ₅	141.27	162.39	179.70	171.045	21.12	38.43	29.775	1.15	1.27	1.210
T ₆	141.27	84.00	86.31	85.155	-57.27	-54.96	-56.115	0.59	0.61	0.600
T ₇	155.67	178.89	188.58	183.735	23.22	32.91	28.065	1.15	1.21	1.180
T ₈	155.67	182.40	208.98	195.690	26.73	53.31	40.020	1.17	1.34	1.255
T ₉	155.67	86.10	94.29	90.195	-69.57	-61.38	-65.475	0.55	0.61	0.580
T ₁₀	170.07	187.68	212.19	199.935	17.61	42.12	29.865	1.10	1.25	1.175
T ₁₁	170.07	216.99	253.20	235.095	46.92	83.13	65.025	1.28	1.49	1.385
T ₁₂	170.07	92.32	96.39	94.355	-77.75	-73.68	-75.715	0.54	0.57	0.555

Rate: Seedlings-Rs.60/100seedlings, Pots-Rs.2/pot, Seaweed-Rs.300/250ml, Selling Price of flowers-according to flower quality and grade

The superior performance of T₁₁ therefore suggests that 7 ml seaweed extract combined with irrigation at three-day intervals provided the most favorable balance between treatment expenditure and monetary return under the experimental conditions. The results emphasize that

seaweed extract concentration and irrigation interval should be considered jointly when making economic recommendations for marigold production, since the financial benefit of increased biostimulant use depends on the water-management regime under which it is applied.

Conclusion

The economic evaluation revealed that T₁₁ (7 ml seaweed extract + three-day irrigation interval) was the most profitable treatment, recording the highest pooled gross return (₹235.095/30 pots), net return (₹65.025/30 pots), and B:C ratio (1.385). The findings indicate that additional input expenditure is economically worthwhile when accompanied by sufficient improvement in monetary returns. Thus, 7 ml seaweed extract combined with a three-day irrigation interval emerged as the most economically promising treatment for marigold production under the experimental conditions.

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