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Effect of humic acid and plant growth regulators on economic returns and profitability of mango cv. Amrapali

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ABSTRACT

The present investigation was conducted to assess the effect of humic acid and plant growth regulators on economic returns and profitability of mango (*Mangifera indica* L.) cv. Amrapali under high-density planting. The experiment was carried out during 2024–25 and 2025–26 at the Horticulture Complex, Maharajpur, Department of Horticulture, College of Agriculture, JNKVV, Jabalpur, Madhya Pradesh. The experiment comprised four levels of humic acid (0, 1.0, 1.5 and 2.0%) and five plant growth regulator treatments, viz., control, GA₃ @ 40 ppm, NAA @ 40 ppm, triacontanol @ 500 ppm and salicylic acid @ 2000 ppm, evaluated in an asymmetrical factorial randomized block design with three replications. Economic parameters including cost of cultivation, gross return, net return and Benefit:Cost (B:C) ratio were calculated for each treatment. The results revealed considerable variation in economic performance among the treatment combinations. Humic acid 1.5% + NAA @ 40 ppm (T₁₃) recorded the highest gross return of ₹6,10,200 and ₹7,35,600 ha⁻¹, net return of ₹4,27,329 and ₹5,39,729 ha⁻¹, and B:C ratios of 3.34 and 3.76 during 2024–25 and 2025–26, respectively. On a two-year basis, In contrast, humic acid 2% + salicylic acid @ 2000 ppm (T₂₀) recorded the lowest pooled B:C ratio of 1.55. Overall, humic acid 1.5% combined with NAA @ 40 ppm provided the most favourable economic returns and profitability under the conditions of the present investigation.

Keywords: *Mangifera indica*, Amrapali, Humic acid, GA₃, Plant growth regulators, Gross return, Net return, B:C ratio, Economic efficiency, Profitability

1. Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical and subtropical fruit crops of India and occupies a prominent position in the national fruit economy because of its high production potential, consumer preference, nutritional value, processing utility and wide varietal diversity (Radha *et al.*, 2007) [1]. India ranks first in mango production and contributes nearly 46 per cent of global production, highlighting the importance of improving productivity and profitability of mango cultivation (Anonymous, 2024–25; FAOSTAT, 2025) [2, 3]. Among commercially important cultivars, ‘Amrapali’, a hybrid of ‘Dashehari’ × ‘Neelum’, is particularly suitable for high-density planting owing to its dwarf stature, regular bearing, high productivity, attractive deep orange-red pulp, high carotenoid content and desirable fruit quality (Singh *et al.*, 2001; Singh *et al.*, 2012) [4]. However, achieving higher productivity and better economic returns requires efficient management practices that can enhance crop performance without disproportionately increasing the cost of cultivation.

Mango production involves substantial expenditure on orchard management, including fertilizers, plant protection, irrigation, labour and other cultural operations. Consequently, increased yield alone does not necessarily ensure greater profitability, particularly when additional inputs are required. Economic evaluation of orchard interventions is therefore essential for determining whether the productivity gains obtained from a particular treatment are sufficient to compensate for its associated input cost. Gross return, which represents the value of produce obtained per unit area, provides an indication of the economic output of a treatment, whereas net return accounts for the cost of cultivation and reflects the actual economic gain. The benefit:cost (B:C) ratio further provides a measure of economic efficiency by relating the returns obtained to the expenditure incurred. These parameters are particularly important for identifying management practices that are not only agronomically effective but also economically feasible for commercial mango production.

Plant growth regulators (PGRs) have considerable potential for improving reproductive development, fruit retention, fruit growth and yield in mango. Naphthalene acetic acid (NAA) is widely used to improve fruit retention and development and has been reported to enhance fruit number, fruit size and yield through reduced fruit abscission (Singh *et al.*, 1983; Rathod *et al.*, 2019) [5, 6]. Gibberellic acid (GA₃), owing to its role in cell elongation and fruit development, has been reported to improve fruit retention, reduce fruit drop and increase fruit size and yield in mango (Ghosh, 2016; Sahu *et al.*, 2020) [7, 8]. Triacontanol, a naturally occur

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ring plant growth regulator, can enhance photosynthetic activity, nutrient utilization and metabolic processes, thereby contributing to improved plant growth and productivity (Naeem *et al.*, 2012) [9]. Its application has also been associated with improved crop productivity and fruit quality under different environmental conditions (Perveen *et al.*, 2022) [10]. Salicylic acid regulates several physiological processes, including photosynthesis, flowering, transpiration and stress responses, and may influence fruit retention and development (Hayat *et al.*, 2010; Khan *et al.*, 2015) [11, 12]. Improvements in yield resulting from these treatments can potentially increase gross and net returns; however, their economic advantage depends on both the magnitude of yield response and the additional cost associated with treatment application.

Humic acid is another important bio-stimulant that may contribute to improved crop productivity by enhancing nutrient availability, root growth, nutrient uptake and microbial activity, besides stimulating physiological and metabolic processes in plants (Pizzeghello *et al.*, 2002) [13]. In mango, application of humic acid has been associated with improvements in vegetative growth, fruit development, fruit weight and yield (Ngullie *et al.*, 2014; Momin *et al.*, 2016; Patel *et al.*, 2019) [14, 15, 16]. Such improvements in productivity may translate into higher economic returns when the increase in output is greater than the additional expenditure on the input. Thus, combining humic acid with suitable PGRs may provide an opportunity to improve orchard productivity while maintaining economic efficiency. Nevertheless, the economic response of such combinations cannot be assumed solely from their physiological or yield effects and needs to be evaluated under specific cultivar and production conditions.

Although several studies have documented the effects of humic acid and PGRs on growth, fruit retention, yield and fruit quality in mango and other fruit crops, comparatively less attention has been given to the economic consequences of their individual and combined application, particularly in high-density mango cv. Amrapali. Information on the extent to which these treatments influence gross returns, net returns and benefit:cost ratio under the agro-climatic conditions of central India is limited. Economic assessment is therefore necessary to identify treatments that provide a favourable balance between input expenditure and monetary returns.

Hence, the present investigation was undertaken to evaluate the effect of different levels of humic acid and plant growth regulators on the economic performance of mango cv. Amrapali, with particular emphasis on gross return, net return and benefit:cost ratio. The study aimed to identify treatment combinations capable of improving economic returns and profitability and to provide an economically relevant basis for selecting suitable humic acid and PGR interventions for commercial mango production under high-density planting conditions.

2. Materials and methods

2.1 Experimental site and plant material

The investigation was carried out during 2024–25 and 2025–26 at the Horticulture Complex, Maharajpur, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India. The experimental location lies at an elevation of approximately 411.78 m above mean sea level and represents the agro-climatic conditions of central India. Five-year-old trees of mango (*Mangifera indica* L.) cv. Amrapali were used for the study. The trees were maintained under a high-density planting system with a spacing of 2.5×5.0 m. The soil at the experimental site was clay loam, slightly alkaline in reaction (pH 7.39), with 0.48% organic carbon and available N, P and K of 265.3, 12.9 and 340.6 kg ha⁻¹, respectively.

2.2 Experimental design and treatments details

The experiment was conducted in an asymmetrical Factorial Randomized Block Design (FRBD) comprising four levels of humic acid and five levels of plant growth regulators (PGRs), with three replications. Thus, 20 treatment combinations were evaluated using 60 experimental trees.

Humic acid treatments consisted of H₀: control, H₁: 1.0%, H₂: 1.5% and H₃: 2.0%. The PGR treatments comprised P₀: control, P₁: GA₃ @ 40 ppm, P₂: NAA @ 40 ppm, P₃: triacontanol @ 500 ppm and P₄: salicylic acid @ 2000 ppm. The treatment combinations included the respective levels of humic acid applied alone or in combination with each PGR.

2.3 Application of treatments

The required concentrations of humic acid and PGRs were prepared separately using water as the spray medium. Fresh spray formulations were prepared immediately before application. Each treatment was applied twice as a foliar spray. The first application was made during the first fortnight of December, prior to flower initiation, while the second application was carried out during the second fortnight of March following fruit set.

Approximately 10 L of spray solution was applied to each tree using a petrol-operated high-pressure portable power sprayer equipped with a hollow-cone nozzle. Spraying was performed during morning hours under suitable environmental conditions to obtain uniform coverage of the canopy, panicles and developing fruits.

2.4 Recording of economic parameters

At harvest, the marketable fruits obtained from each experimental tree were harvested and weighed to determine fruit yield. Yield per hectare was estimated on the basis of tree yield and the planting density of the experimental orchard.

For economic analysis, the prevailing market price of mango fruit during the respective experimental season was considered for calculating the monetary value of produce. The cost of cultivation for each treatment included the common cost of orchard operations together with the additional expenditure incurred for the respective humic acid and PGR treatments. The cost associated with preparation and application of treatment sprays was also incorporated wherever applicable.

The following economic parameters were computed:

Gross return (₹ ha⁻¹)

Gross return was estimated from the monetary value of marketable fruit yield obtained per hectare:

$$\text{Gross return} = \text{Marketable fruit yield (kg ha}^{-1}\text{)} \times \text{prevailing fruit price (₹ kg}^{-1}\text{)}$$

Net return (₹ ha⁻¹)

Net return was calculated by deducting the total cost of cultivation from the corresponding gross return:

$$\text{Net return} = \text{Gross return} - \text{Total cost of cultivation}$$

Benefit cost ratio (B:C ratio)

The benefit cost ratio was calculated to determine the economic efficiency of each treatment:

$$\text{B:C ratio} = \text{Gross return} / \text{Total cost of cultivation}$$

The economic parameters were calculated separately for each treatment and experimental year, and pooled values were obtained where appropriate.

2.5 Statistical analysis

The experimental observations were subjected to analysis of variance (ANOVA) following the procedure applicable to the factorial experimental design. The significance of humic acid levels, PGR treatments and their interaction was tested using the *F*-test. Treatment means were compared at the 5% probability level using the Critical Difference (CD) wherever the corresponding treatment effect was significant. Standard error of mean (SEM_±), standard error of difference (SE_d) and Critical Difference were calculated following the standard statistical procedure.

3. Results and discussion

3.1 Cost of cultivation

The cost of cultivation varied among the different treatment combinations owing to differences in the quantity and type of humic acid and plant growth regulators applied. During 2024–25, the cost of cultivation ranged from ₹1,32,631 ha⁻¹ in the untreated control (T₁) to ₹2,27,991 ha⁻¹ under humic acid 2% + GA₃ @ 40 ppm (T₁₇). During 2025–26, the corresponding range was ₹1,45,631 to ₹2,40,991 ha⁻¹. The higher cost under the combined treatments was primarily associated with the additional expenditure incurred on humic acid, PGRs and their application (Table 1).

Among the humic acid treatments, increasing the concentration of humic acid generally increased the cost of cultivation. For example, humic acid alone at 1% (T₆), 1.5% (T₁₁) and 2% (T₁₆) resulted in cultivation costs of ₹1,64,631, ₹1,80,631 and ₹1,96,631 ha⁻¹, respectively, during 2024–25. A similar pattern was observed during 2025–26, with corresponding costs of ₹1,77,631, ₹1,93,631 and ₹2,09,631 ha⁻¹. Likewise, among the PGR combinations, treatments involving GA₃ and salicylic acid generally incurred greater expenditure than the corresponding NAA and triacontanol combinations.

The relatively higher cultivation cost of PGR + humic acid treatments, however, needs to be evaluated in relation to their returns rather than independently. Treatments that generated greater fruit yield and consequently higher gross returns were able to offset the additional expenditure and provide higher net returns and B:C ratios. Similar economic implications of growth-regulator application have been reported in mango by Momin *et al.* (2016) [15] and Patel *et al.* (2021) [17], where increased expenditure on growth-regulating inputs was associated with improved yield and economic returns.

3.2 Gross return

Gross return exhibited considerable variation among treatments in both years. During 2024–25, gross return ranged from ₹2,62,800 ha⁻¹ in the untreated control (T₁) to ₹6,10,200 ha⁻¹ under humic acid 1.5% + NAA @ 40 ppm (T₁₃). During 2025–26, gross return ranged from ₹2,96,400 ha⁻¹ in the control (T₁) to ₹7,35,600 ha⁻¹ under T₁₃.

The treatment comprising humic acid 1.5% + NAA @ 40 ppm (T₁₃) recorded the highest gross return in both years. It was closely followed by humic acid 1.5% + triacontanol @ 500 ppm (T₁₄), which recorded gross returns of ₹6,06,600 and ₹7,31,200 ha⁻¹ during 2024–25 and 2025–26, respectively. Humic acid 1% + NAA @ 40 ppm (T₈) also performed well, recording ₹5,51,160 and ₹6,68,400 ha⁻¹, while humic acid 1% + triacontanol @ 500 ppm (T₉) recorded ₹5,42,880 and ₹6,46,000 ha⁻¹, respectively.

On the basis of the two-year mean, the highest gross return was recorded under T₁₃ (₹6,72,900 ha⁻¹), followed by T₁₄ (₹6,68,900 ha⁻¹), T₈ (₹6,09,780 ha⁻¹), T₉ (₹5,94,440 ha⁻¹) and T₁₂ (₹5,93,900 ha⁻¹). The control (T₁) recorded a pooled gross return of ₹2,79,600 ha⁻¹. Thus, the pooled gross return under T₁₃ was approximately 140.7% greater than that of the control.

The higher gross returns under humic acid and PGR combinations may be associated with their favourable effects on fruit retention, fruit development and overall fruit productivity. Humic substances have been reported to influence plant physiological processes and nutrient utilization, while NAA is widely associated with improved fruit retention through modulation of fruit abscission. Patel *et al.* (2019) [16] reported that foliar application of humic acid improved fruit retention and yield in mango cv. Amrapali. Momin *et al.* (2016) [15] also observed improvement in fruit retention, yield and quality attributes with foliar application of growth-regulating substances in mango cv. Kesar.

The present findings are further supported by Patel *et al.* (2021) [17], who reported improvement in yield-related parameters and economic returns through the application of new-generation PGRs in mango cv. Dashehari. The favourable performance of triacontanol-containing treatments in the present study is also consistent with the observations of Momin *et al.* (2016) [15], while Naeem *et al.* (2012) [9] described

triacontanol as an effective plant growth regulator capable of influencing plant growth and productivity. Thus, the greater gross returns obtained under T₁₃ and T₁₄ can be related primarily to the greater economic value of fruit production under these treatment combinations.

3.3 Net return

Net return, which represents the gross return remaining after deduction of the cost of cultivation, varied substantially among the treatments. During 2024–25, net return ranged from ₹1,17,589 ha⁻¹ under humic acid 2% + salicylic acid @ 2000 ppm (T₂₀) to ₹4,27,329 ha⁻¹ under humic acid 1.5% + NAA @ 40 ppm (T₁₃). During 2025–26, net return ranged from ₹1,37,069 ha⁻¹ under T₂₀ to ₹5,39,729 ha⁻¹ under T₁₃.

Humic acid 1.5% + NAA @ 40 ppm (T₁₃) consistently recorded the highest net return during both years. The treatment was followed by humic acid 1.5% + triacontanol @ 500 ppm (T₁₄), which recorded net returns of ₹4,23,169 and ₹5,34,769 ha⁻¹ during 2024–25 and 2025–26, respectively. Humic acid 1% + NAA @ 40 ppm (T₈) recorded ₹3,84,289 and ₹4,88,529 ha⁻¹, whereas humic acid 1% + triacontanol @ 500 ppm (T₉) recorded ₹3,75,449 and ₹4,65,569 ha⁻¹, respectively.

The pooled net return followed the same trend. T₁₃ recorded the highest two-year mean net return of ₹4,83,529 ha⁻¹, followed by T₁₄ (₹4,78,969 ha⁻¹), T₈ (₹4,36,409 ha⁻¹), T₉ (₹4,20,509 ha⁻¹) and T₁₂ (₹3,75,409 ha⁻¹). The control recorded a pooled net return of ₹1,40,469 ha⁻¹. Consequently, the pooled net return under T₁₃ was approximately 244.2% greater than the control.

The higher net return under T₁₃ indicates that the additional expenditure associated with humic acid and NAA application was compensated by the higher gross income generated from fruit production. An important feature of the present results was that the treatment with the lowest cultivation cost did not necessarily produce the highest net return. Rather, economic performance depended on the balance between additional input expenditure and the additional value of fruit production.

The present results are consistent with the findings of Patel *et al.* (2019) [16], who reported improved fruit yield under humic acid application in mango cv. Amrapali. Similarly, Momin *et al.* (2016) [15] observed improved economic performance associated with enhanced fruit retention and yield under foliar application of growth-regulating substances in mango cv. Kesar. Patel *et al.* (2021) [17] also reported improved economic returns from suitable PGR treatments in mango cv. Dashehari. These findings support the importance of selecting treatment combinations on the basis of both yield response and input cost.

The response of NAA observed in the present study is also comparable with the findings of Vidyullatha *et al.* (2022) [18], who reported improvement in yield and economic parameters following NAA application in muskmelon. Although the crop and production conditions differed, their findings provide additional evidence for the potential of NAA to improve economic output through its influence on reproductive and yield-related processes.

3.4 Benefit:Cost (B:C) ratio

The Benefit:Cost (B:C) ratio provides an important measure of economic efficiency because it relates the gross income generated to the expenditure incurred for crop production. The B:C ratio varied among treatments in both experimental years. During 2024–25, the B:C ratio ranged from 1.52 under humic acid 2% + salicylic acid @ 2000 ppm (T₂₀) to 3.34 under humic acid 1.5% + NAA @ 40 ppm (T₁₃). During 2025–26, the corresponding range was 1.58 to 3.76. The control recorded B:C ratios of 1.98 and 2.04 during the two respective years. The highest B:C ratio in both years was recorded under humic acid 1.5% + NAA @ 40 ppm (T₁₃), with values of 3.34 and 3.76. Humic acid 1.5% + triacontanol @ 500 ppm (T₁₄) recorded B:C ratios of 3.31 and 3.72, while humic acid 1% + NAA @ 40 ppm (T₈) recorded 3.30 and 3.72 in the respective years. Humic acid 1% + triacontanol

@ 500 ppm (T₉) also produced a comparatively high B:C ratio of 3.24 and 3.58. These treatments therefore combined relatively high gross returns with cultivation costs that remained proportionate to the additional income generated.

The higher B:C ratio obtained with humic acid 1.5% + NAA @ 40 ppm may be attributed to the favourable balance between treatment cost and the increased gross return obtained from fruit production. Momin *et al.* (2016) [15] reported improved economic efficiency with suitable foliar growth-regulator treatments in mango cv. Kesar, while Patel *et al.* (2021) [17] reported improvement in economic returns and B:C ratio through appropriate PGR application in mango cv. Dashehari. Patel *et al.* (2019) [16] also demonstrated the potential of humic acid application to improve yield-related performance in mango cv. Amrapali, which consequently has implications for profitability.

The results also indicate that the economic response was dependent on the particular combination of humic acid concentration and PGR. The 1.5% humic acid level in combination with NAA or triacontanol produced considerably higher economic returns than the corresponding higher-concentration combinations with salicylic acid. Therefore, economic evaluation should consider not only the yield response but also the additional cost associated with each treatment.

Overall, the economic analysis demonstrated substantial variation in cultivation cost, gross return, net return and B:C ratio among the

tested treatments. Among all combinations, humic acid 1.5% + NAA @ 40 ppm (T₁₃) recorded the highest gross return (₹6,10,200 and ₹7,35,600 ha⁻¹), net return (₹4,27,329 and ₹5,39,729 ha⁻¹) and B:C ratio (3.34 and 3.76) during 2024–25 and 2025–26, respectively. On a two-year basis, T₁₃ recorded ₹6,72,900 ha⁻¹ gross return, ₹4,83,529 ha⁻¹ net return and a B:C ratio of 3.55. Humic acid 1.5% + triacontanol @ 500 ppm (T₁₄) showed a closely comparable economic response, indicating that both treatment combinations were associated with favourable economic performance under the conditions of the present investigation.

Conclusion

The economic analysis demonstrated considerable variation among humic acid and plant growth regulator treatments in mango cv. Amrapali. Humic acid 1.5% + NAA @ 40 ppm (T₁₃) recorded the highest gross return of ₹6,10,200 and ₹7,35,600 ha⁻¹, net return of ₹4,27,329 and ₹5,39,729 ha⁻¹, and B:C ratios of 3.34 and 3.76 during 2024–25 and 2025–26, respectively. On a two-year basis, T₁₃ recorded ₹6,72,900 ha⁻¹ gross return, ₹4,83,529 ha⁻¹ net return and a B:C ratio of 3.55. Humic acid 1.5% + triacontanol @ 500 ppm (T₁₄) showed a closely comparable economic response. Overall, the 1.5% humic acid + NAA @ 40 ppm treatment provided the most favourable economic returns under the conditions of the experiment.

Treatment Detail	Cost of cultivation 1st Year (2024-25) Rs/ha	Cost of cultivation 2nd year (2025-26) Rs/ha	Gross Return 1st Year (2024-25) Rs/ha	Gross Return 2nd year (2025-26) Rs/ha	Net Return 1st Year (2024-25) Rs/ha	Net Return 2nd year (2025-26) Rs/ha	C:B Ratio 1st Year (2024-25)	C:B Ratio 2nd year (2025-26)
T ₁ (control)	132631	145631	262800	296400	130169	150769	1.98	2.04
T ₂ (GA ₃ @ 40 ppm)	163991	176991	343440	409600	179449	232609	2.09	2.31
T ₃ (NAA @ 40 ppm)	134871	147871	345600	416400	210729	268529	2.56	2.82
T ₄ (triacontanol @ 500 ppm)	135431	148431	348840	420800	213409	272369	2.58	2.83
T ₅ (salicylic acid @ 2000 ppm)	161131	174131	320040	356400	158909	182269	1.99	2.05
T ₆ (humic acid 1%)	164631	177631	343800	405600	179169	227969	2.09	2.28
T ₇ (humic acid 1% + GA ₃ @ 40 ppm)	195991	208991	491760	572400	295769	363409	2.51	2.74
T ₈ (humic acid 1% + NAA @ 40 ppm)	166871	179871	551160	668400	384289	488529	3.30	3.72
T ₉ (humic acid 1% + Triacontanol @ 500 ppm)	167431	180431	542880	646000	375449	465569	3.24	3.58
T ₁₀ (humic acid 1% + Salicylic acid @ 2000 ppm)	193131	206131	442800	513200	249669	307069	2.29	2.49
T ₁₁ (humic acid 1.5%)	180631	193631	448200	520800	267569	327169	2.48	2.69
T ₁₂ (humic acid 1.5% + Ga ₃ @ 40 ppm)	211991	224991	541800	646000	329809	421009	2.56	2.87
T ₁₃ (humic acid 1.5% + NAA @ 40 ppm)	182871	195871	610200	735600	427329	539729	3.34	3.76
T ₁₄ (humic acid 1.5% + Triacontanol @ 500 ppm)	183431	196431	606600	731200	423169	534769	3.31	3.72
T ₁₅ (humic acid 1.5% + Salicylic acid @ 2000 ppm)	209131	222131	496440	578000	287309	355869	2.37	2.60
T ₁₆ (humic acid 2%)	196631	209631	414720	470800	218089	261169	2.11	2.25
T ₁₇ (humic acid 2% + Ga ₃ @ 40 ppm)	227991	240991	480600	551200	252609	310209	2.11	2.29

(continued on next page)

Treatment Detail	Cost of cultivation 1st Year (2024-25) Rs/ha	Cost of cultivation 2 nd year (2025-26) Rs/ha	Gross Return 1st Year (2024-25) Rs/ha	Gross Return 2 nd year (2025-26) Rs/ha	Net Return 1 st 1st Year (2024-25) Rs/ha	Net Return 2 nd year (2025-26) Rs/ha	C:B Ratio 1st Year (2024-25)	C:B Ratio 2 nd year (2025-26)
T ₁₈ (humic acid 2% + NAA @ 40 ppm)	198871	211871	509760	608800	310889	396929	2.56	2.87
T ₁₉ (humic acid 2% + Triaccontanol @ 500 ppm)	199431	212431	497880	576000	298449	363569	2.50	2.71
T ₂₀ (humic acid 2% + Salicylic acid @ 2000 ppm)	225131	238131	342720	375200	117589	137069	1.52	1.58

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- Table:1 Economic returns and profitability of mango cv. Amrapali as influenced by humic acid and plant growth regulators during 2024-25 and 2025-26.

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