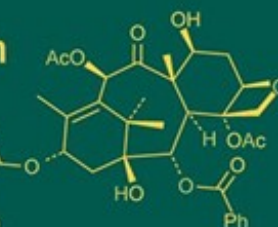


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Influence of humic acid and plant growth regulators on edible pulp fraction and fruit tissue partitioning in mango cv Amrapali

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ABSTRACT

A field experiment was conducted during 2024-25 and 2025-26 at the Horticulture Complex, Maharajpur, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India, to evaluate the effects of humic acid and plant growth regulators (PGRs) on fruit composition and edible fraction of mango (*Mangifera indica* L.) cv. Amrapali. Trees maintained under a high density planting system (2.5 × 5.0 m) were subjected to different concentrations of humic acid and PGRs, including GA₃, NAA, triacontanol and salicylic acid, in an asymmetrical factorial treatment arrangement. The treatments significantly influenced pulp percentage, whereas peel and stone percentages were not significantly affected. Among the humic acid treatments, 1.5% humic acid recorded the highest pooled pulp percentage (75.85%) compared with 64.31% in the untreated control. Among PGRs, GA₃ at 40 ppm was most effective, producing 75.12% pulp, followed by NAA at 40 ppm (74.22%). A significant humic acid × PGR interaction was observed, with 1.5% humic acid + GA₃ at 40 ppm producing the highest pooled pulp percentage. In comparison, the untreated combination recorded 61.51% pulp. The findings demonstrate that integrated application of humic acid at 1.5% with GA₃ at 40 ppm is a promising approach for enhancing edible pulp recovery and favourable fruit tissue partitioning in mango cv. Amrapali.

Keywords: *Mangifera indica*, Amrapali, Humic acid, GA₃, Plant growth regulators, Pulp percentage, Fruit composition, Edible fraction

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical and subtropical fruit crops of India and is widely valued for its distinctive flavour, nutritional richness, processing potential and considerable varietal diversity (Radha *et al.*, 2007) [1]. India ranks first in mango production and contributes nearly 46 per cent of global production, emphasizing the importance of improving both productivity and fruit quality (Anonymous, 2024-25; FAOSTAT, 2025) [2, 3]. Among the commercially important mango cultivars, 'Amrapali', a hybrid of 'Dashehari' × 'Neelum', is particularly promising because of its dwarf stature, regular bearing, high productivity, attractive deep orange-red pulp, high carotenoid content and superior pulp percentage (Singh *et al.*, 2001; Singh *et al.*, 2012) [4, 5]. Thus, improvement of fruit quality and edible portion in 'Amrapali' is of considerable importance for both fresh consumption and processing purposes.

Fruit quality in mango is determined not only by biochemical characteristics such as total soluble solids, sugars, acids and vitamins, but also by the relative proportion of its major structural components. The edible pulp constitutes the principal economic portion of the fruit, whereas peel and stone represent non-edible fractions. Therefore, pulp percentage, peel percentage and stone percentage are important physical quality parameters that directly indicate the proportion of usable fruit material.

Fruit development is a complex physiological process involving cell division, cell enlargement, assimilate accumulation and coordinated hormonal regulation. Consequently, manipulation of plant growth and hormonal balance through exogenous application of plant growth regulators (PGRs) and bio-stimulants may influence fruit size, tissue development and the relative proportion of pulp, peel and stone. Naphthalene acetic acid (NAA) has been widely used in mango for improving fruit retention and fruit development. Foliar application of NAA has been reported to improve fruit retention, fruit size and yield by reducing ethylene-induced abscission (Singh and Ram, 1983; Rathod *et al.*, 2019). Such improvement in fruit development may potentially alter the allocation of assimilates among pulp, peel and stone tissues.

Gibberellic acid (GA₃) is another important growth regulator involved in cell elongation and fruit development. Application of GA₃ during pea and marble stages has been reported to improve fruit retention, reduce fruit drop and enhance fruit size and yield in mango (Ghosh, 2016; Sahu *et al.*, 2020) [6, 7]. Triacontanol, a

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naturally occurring plant growth regulator, enhances photosynthesis, nutrient uptake and enzyme activity and may consequently improve overall plant productivity and fruit development (Naeem *et al.*, 2012) [8]. Its application has also been associated with improved growth, stress tolerance, fruit yield and quality under adverse environmental conditions (Perveen *et al.*, 2022) [9].

Humic acid acts as an important bio-stimulant by improving nutrient availability, root development and microbial activity, while stimulating cell division and biomass production (Pizzeghello *et al.*, 2002) [10]. These effects can influence assimilate supply during fruit development and thereby affect physical fruit composition. Salicylic acid regulates several physiological processes, including photosynthesis, flowering, transpiration and stress tolerance, and has been reported to influence ethylene biosynthesis and fruit retention (Hayat *et al.*, 2010; Khan *et al.*, 2015) [11, 12]. Foliar application of PGRs and bio-stimulants can therefore modify physiological efficiency and fruit development, with reported improvements in fruit size, weight and other quality attributes (Singh, 2002).

Despite considerable research on individual plant growth regulators, responses to these treatments may differ according to cultivar and agro-climatic conditions. Moreover, limited information is available regarding their individual and combined effects on the relative distribution of edible and non-edible components of mango fruit, particularly in cv. Amrapali. Hence, the present investigation was undertaken to evaluate the effects of different foliar-applied PGRs and humic acid treatments on pulp percentage, peel percentage, stone percentage, with the aim of identifying treatments capable of improving edible fruit portion and overall fruit quality in mango cv. Amrapali.

2. Materials and methods

2.1 Experimental site and plant material

The experiment was conducted 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 site is situated at an elevation of approximately 411.78 m above mean sea level and represents the agro-climatic conditions of central India. The study was carried out on five-year-old mango (*Mangifera indica* L.) cv. Amrapali trees maintained under a high-density planting system at a spacing of 2.5 × 5.0 m. The experimental soil was clay loam in texture with slightly alkaline reaction (pH 7.39), low organic carbon (0.48%) and available N, P and K contents of 265.3, 12.9 and 340.6 kg ha⁻¹, respectively.

2.2 Experimental design and treatments

The experiment was laid out in an asymmetrical Factorial Randomized Block Design (FRBD) with three replications. Four levels of humic acid and five levels of plant growth regulators (PGRs) were evaluated, resulting in 20 treatment combinations involving a total of 60 experimental trees. The treatments consisted of humic acid at 0, 1.0, 1.5 and 2.0 per cent and PGRs comprising control, GA₃ @ 40 ppm, NAA @ 40 ppm, triacontanol @ 500 ppm and salicylic acid @ 2000 ppm.

The treatment combinations were: T₁ = control; T₂ = GA₃ @ 40 ppm; T₃ = NAA @ 40 ppm; T₄ = triacontanol @ 500 ppm; T₅ = salicylic acid @ 2000 ppm; T₆ = humic acid 1%; T₇–T₁₀ = humic acid 1% in combination with GA₃, NAA, triacontanol and salicylic acid, respectively; T₁₁ = humic acid 1.5%; T₁₂–T₁₅ = humic acid 1.5% in combination with GA₃, NAA, triacontanol and salicylic acid, respectively; and T₁₆ = humic acid 2%, while T₁₇–T₂₀ comprised humic acid 2% in combination with GA₃, NAA, triacontanol and salicylic acid, respectively.

2.3 Preparation and application of treatments

Humic acid solutions were prepared at 1.0, 1.5 and 2.0% concentrations using a commercial liquid formulation. GA₃ and NAA solutions were prepared at 40 ppm, triacontanol at 500 ppm and salicylic acid at 2000 ppm. The required quantities of the respective chemicals were dissolved and diluted with water to obtain the desired concentrations. Fresh spray solutions were prepared immediately before application.

All treatments were applied as foliar sprays twice during the experimental period. The first spray was applied during the first fortnight of December, before flower initiation, and the second spray during the second fortnight of March after fruit set. Approximately 10 L of spray solution was applied per tree using a petrol-operated high-pressure portable power sprayer fitted with a hollow-cone nozzle to ensure uniform coverage of the canopy, panicles and developing fruits. Spraying was carried out during morning hours under favourable environmental conditions.

2.4 Sampling of fruits

At harvest, five marketable fruits were randomly selected from each experimental tree for recording physical fruit characteristics. The fruits were weighed individually using a calibrated electronic weighing balance. Each fruit was subsequently separated into pulp, peel and stone. Peel and stone were carefully removed and weighed separately. The pulp weight was obtained from the total fruit weight and the weights of peel and stone.

2.5 Estimation of pulp, peel and stone percentages

Pulp percentage was calculated to determine the proportion of edible pulp in relation to total fruit weight:

$$\text{Pulp percentage (\%)} = \left[\frac{\text{Pulp weight (g)}}{\text{Total fruit weight (g)}} \right] \times 100$$

Similarly, peel percentage was calculated as:

$$\text{Peel percentage (\%)} = \left[\frac{\text{Peel weight (g)}}{\text{Total fruit weight (g)}} \right] \times 100$$

Stone percentage was calculated using:

$$\text{Stone percentage (\%)} = \left[\frac{\text{Stone weight (g)}}{\text{Total fruit weight (g)}} \right] \times 100$$

The mean values were calculated from five randomly selected fruits for each experimental tree and expressed as percentage.

2.6 Statistical analysis

The observations recorded for pulp percentage, peel percentage, stone percentage, were subjected to analysis of variance (ANOVA) appropriate for the factorial experimental design. The effects of humic acid,

PGRs and their interaction were tested for statistical significance using the *F*-test. Treatment means were compared using the Critical Difference (CD) at the 5% level of significance whenever the treatment effect was significant. Standard error of mean (SEM_±), standard error of difference (SE_d) and CD were calculated according to the prescribed procedure.

3. Result and discussion

3.1 Pulp percentage

Fruit composition was differentially influenced by humic acid and plant growth regulator (PGR) treatments, with the most pronounced responses observed for pulp percentage and pulp-based fruit quality indices. Humic acid at 1.5% (H₂) significantly increased pulp percentage, recording pooled values of 75.85%, compared with 64.31% under the untreated control (H₀). Among the PGR treatments, GA₃ at 40 ppm (P₁) produced the highest pooled pulp percentage (75.12%), followed by NAA at 40 ppm (74.22%). The significant response to humic acid is consistent with earlier observations that humic substances can stimulate fruit growth and edible tissue development. In mango cv. Kesar, Momin (2016) [13] reported improved fruit weight and volume with humic acid application, while Patel *et al.* (2019) [14] observed favourable responses to 1.5% humic acid in mango cv. Amrapali, particularly for fruit size and yield. Aal *et al.* (2024) [15] further reported that 1.5% humic acid increased fruit weight and pulp weight in Kesar mango.

The extent of the response was further enhanced when humic acid was combined with GA₃. The interaction treatment H₂P₁ (humic acid

1.5% + GA₃ 40 ppm) recorded the highest pulp percentage of 79.01% in pooled analysis, compared with only 61.51% under H₀P₀, representing an improvement of approximately 28.4% over the untreated combination. The superiority of H₂P₁ was consistent across both seasons, with pulp percentage increasing from 78.24 to 79.77% in the two respective years. H₂P₁ was statistically at par with H₂P₂, H₁P₁ and H₁P₂, indicating that several optimized combinations were capable of producing a high edible fraction, although H₂P₁ numerically remained the most favourable treatment.

The favourable response to GA₃ is supported by the findings of Singh *et al.* (2017) [16], who specifically evaluated GA₃ in mango cv. Amrapali and reported that GA₃ at 40 ppm produced 242 g fruit weight, 12.20 cm fruit length, 7.48 cm fruit width, 256.33 cc fruit volume and 55.60 kg plant⁻¹ yield. The agreement between the present study and this earlier work is particularly noteworthy because the same cultivar and GA₃ concentration were involved. It suggests that 40 ppm GA₃ represents an effective concentration for promoting fruit development in Amrapali, although the present experiment additionally demonstrates its favourable interaction with humic acid in determining pulp proportion.

Table 1. Effect of foliar application of PGR, Humic Acid and their interaction on Pulp percentage

H/P	First Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	60.90	67.00	65.65	62.67	61.94	63.63
H ₁	67.60	77.45	76.68	72.06	69.86	72.73
H ₂	71.35	78.24	77.95	75.18	72.92	75.13
H ₃	69.19	74.70	73.60	64.36	63.82	69.13
Mean P	67.26	74.35	73.47	68.57	67.14	
	H		P		H*P	
SE(m) ±	0.599		0.670		1.339	
CD at 5%	1.715		1.917		3.834	
CV (%)	3.30					
H/P	Second Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	62.12	68.48	67.08	63.98	63.24	64.98
H ₁	68.82	79.02	78.10	73.40	71.12	74.09
H ₂	72.59	79.77	79.66	76.58	74.23	76.57
H ₃	70.54	76.27	75.07	65.60	65.10	70.52
Mean P	68.52	75.89	74.98	69.89	68.42	
	H		P		H*P	
SE(m) ±	1.495		1.671		3.342	
CD at 5%	4.279		4.785		9.569	
CV (%)	8.09					
H/P	Pooled					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	61.51	67.74	66.37	63.33	62.59	64.31
H ₁	68.21	78.24	77.39	72.73	70.49	73.41
H ₂	71.97	79.01	78.81	75.88	73.58	75.85
H ₃	69.87	75.49	74.34	64.98	64.46	69.83
Mean P	67.89	75.12	74.22	69.23	67.78	
	H		P		H*P	
SE(m) ±	0.818		0.914		1.829	
CD at 5%	2.341		2.618		5.235	
CV (%)	4.47					

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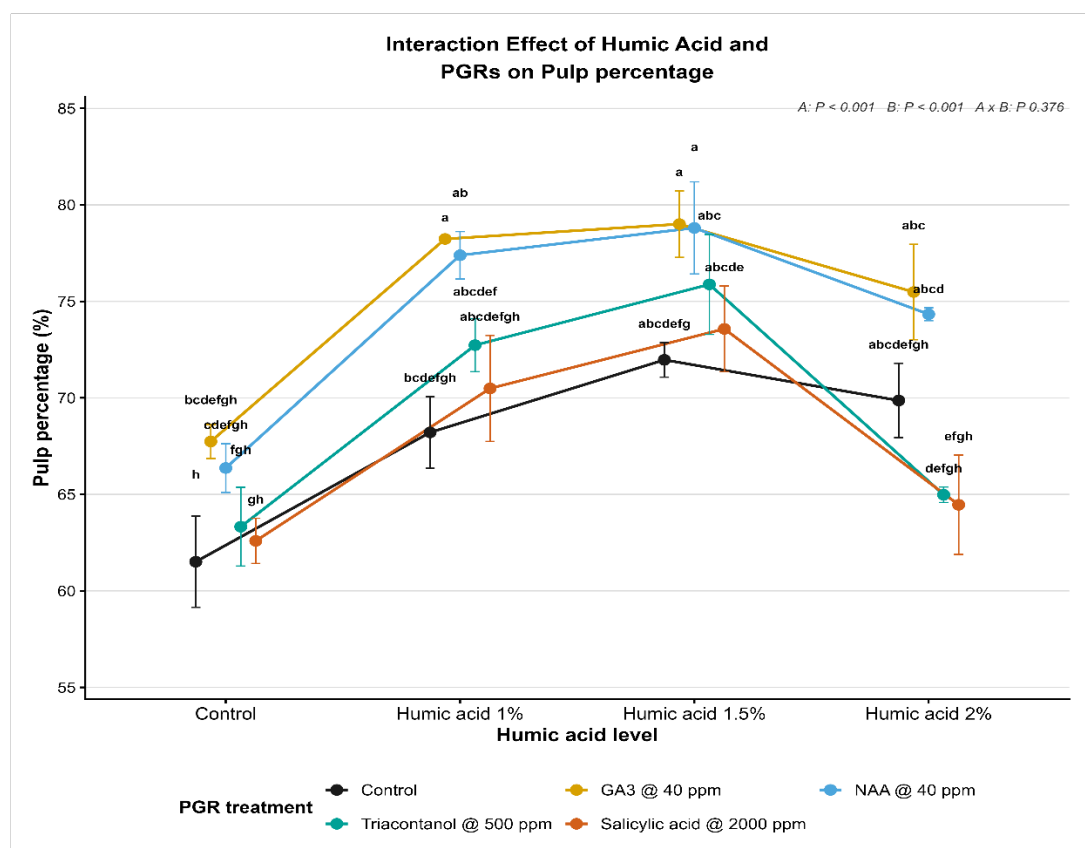


Figure 1. Effect of foliar application of PGR and Humic Acid interaction on Pulp percentage in pooled.

3.2 Peel percentage

In contrast to pulp-related attributes, peel percentage and stone percentage were not significantly influenced by humic acid, PGRs or their interaction in either season or pooled analysis. Although numerical variation was apparent, these differences should not be interpreted as treatment induced reductions because the corresponding statistical

effects were non-significant. For peel percentage, the pooled values ranged numerically from 14.13% under H₂ to 21.30% under H₀, while GA₃ 40 ppm recorded 14.68% compared with 21.33% under salicylic acid 2000 ppm. At the interaction level, H₂P₁ recorded the lowest numerical peel proportion (12.13%), whereas H₀P₀ recorded the highest (22.90%).

Table 1. Effect of foliar application of PGR, Humic Acid and their interaction on Peel percentage

H/P	First Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	23.29	19.88	20.57	22.22	22.67	21.73
H ₁	19.48	13.04	13.66	16.46	17.92	16.11
H ₂	16.78	12.61	12.78	14.88	16.01	14.61
H ₃	18.24	15.13	15.66	21.36	21.53	21.95
Mean P	19.45	15.17	15.67	18.73	23.99	
	H		P		H*P	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	8.17					
H/P	Second Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	22.50	18.95	19.68	21.39	21.84	20.87
H ₁	18.58	12.05	12.80	15.53	17.04	15.20
H ₂	15.86	11.65	11.69	13.94	15.07	13.64
H ₃	17.33	14.12	14.72	20.50	20.73	17.48
Mean P	18.57	14.19	14.72	17.84	18.67	
	H		P		H*P	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	8.09					

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H/P	First Year					Mean H
H/P	P ₀	P ₁	P ₂	P ₃	P ₄	Mean H
H ₀	22.90	19.42	20.13	21.81	22.26	21.30
H ₁	19.03	12.55	13.23	16.00	17.48	15.66
H ₂	16.32	12.13	12.24	14.41	15.54	14.13
H ₃	17.79	14.63	15.19	20.93	21.13	19.72
Mean P	19.01	14.68	15.20	18.29	21.33	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	7.68					

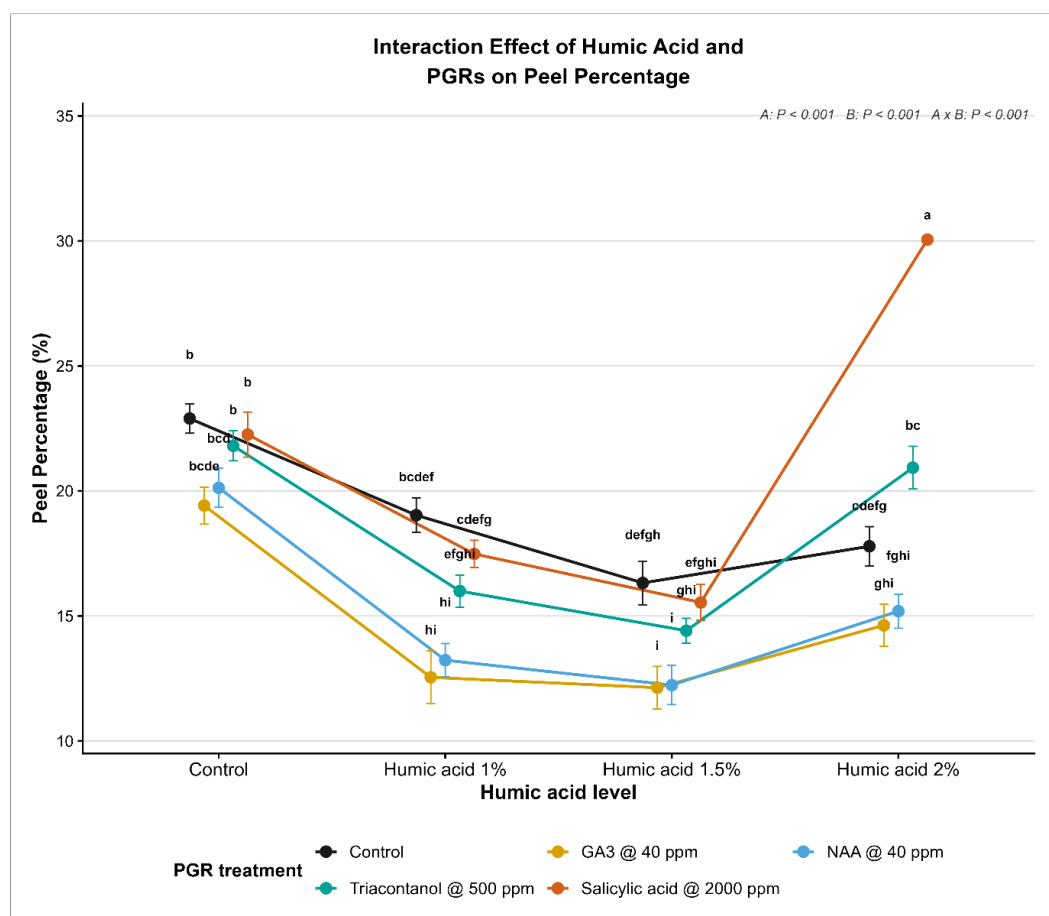


Figure 2. Effect of foliar application of PGR and Humic Acid interaction on Peel percentage in pooled.

3.3 Stone percentage

Pooled stone percentage ranged numerically from 10.03% under H₂ to 14.40% under H₀. GA₃ 40 ppm recorded 10.21%, compared with 13.11% under salicylic acid 2000 ppm, while H₂P₁ recorded the lowest numerical stone proportion (8.87%) and H₀P₀ the highest (15.60%). These numerical patterns are directionally consistent with the higher pulp-based ratios observed under H₂P₁, but the absence of statistical significance indicates that the principal treatment response was expressed through enhancement of pulp development rather than a demonstrable reduction in peel or stone formation.

The physiological basis of this response may involve complementary effects of humic substances and GA₃ on fruit development. Humic substances have been associated with improved nutrient availability, root activity, chlorophyll formation and overall plant physiological efficiency, whereas GA₃ is well recognized for its role in cell expansion and fruit growth. Ferrara *et al.* (2008) [17], for example, reported improvements in chlorophyll status, berry size and fruit quality following humic acid application in table grape, while Yildirim (2007) [18]

observed improvements in fruit size and quality attributes following humic acid treatment in tomato. These findings provide physiological support for the enhanced fruit development observed under humic acid treatment. However, because nutrient uptake, photosynthetic rate, endogenous hormone concentrations and assimilate partitioning were not measured in the present study, a direct mechanistic claim of synergism between humic acid and GA₃ would be premature.

The performance of triacontanol and salicylic acid further illustrates the specificity of PGR responses. Triacontanol has previously been shown to improve fruit growth and productivity in mango. Paralkar *et al.* (2020) [19] reported 289.68 g fruit weight, 284.25 ml fruit volume, 192.23 g pulp weight and 55.76 kg tree⁻¹ yield under triacontanol treatment in Kesar mango. Dash *et al.* (2021) [20] reported 183.50 g fruit weight and 22.38 kg tree⁻¹ yield under triacontanol application in Arka Neelachal Kesri mango. Samant *et al.* (2025) [21] also reported improvements in fruit retention, yield, TSS, sugars, vitamin C and dry matter under triacontanol at 5 ppm in Banganpalli mango. These results confirm the broader growth-promoting potential of triacontanol, although the present data indicate that it was less effective

than GA₃ 40 ppm for modifying the specific pulp-related attributes examined.

Salicylic acid, in contrast, has been more consistently associated with improvements in fruit retention and biochemical quality than with changes in fruit anatomical fractions. Ngullie *et al.* (2014) [22] reported that SA at 2000 ppm improved flowering and fruit retention while increasing TSS and reducing acidity in mango. Similarly, Lohakare *et al.* (2024) [23] found that NAA 25 ppm + SA 100 ppm + ZnSO₄ 0.5% improved fruit yield, fruit size, fruit weight, firmness, pulp weight, TSS and ascorbic acid in Kesar mango. Thus, the comparatively limited response of SA for pulp percentage and tissue partitioning in the present experiment does not imply a lack of physiologi-

cal effectiveness; rather, it indicates that its principal benefits may be expressed through other components of fruit quality.

Overall, the present findings demonstrate that humic acid at 1.5% and GA₃ at 40 ppm were the most effective individual treatments for improving the edible fraction of mango fruit, whereas their combined application (H₂P₁) produced the most favourable overall fruit partitioning. The H₂P₁ treatment increased pooled pulp percentage from 61.51 to 79.01%, relative to H₀P₀. Importantly, these improvements occurred without statistically significant changes in peel and stone percentages. The results therefore indicate that the major treatment advantage was associated with enhanced development of edible pulp and improved pulp-to-non-edible tissue relationships, rather than a statistically demonstrable suppression of peel or stone formation.

Table 2. Effect of foliar application of PGR, Humic Acid and their interaction on Stone percentage

H/P	First Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	15.82	13.12	13.78	15.11	15.39	14.64
H ₁	12.92	9.52	9.65	11.48	12.21	11.16
H ₂	11.87	9.15	9.27	9.94	11.07	10.26
H ₃	12.56	10.17	10.75	14.28	14.61	12.47
Mean P	13.29	10.49	10.86	12.70	13.32	
	H		P		H*P	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	15.01					
H/P	Second Year					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	15.38	12.58	13.23	14.62	14.92	14.15
H ₁	12.60	8.94	9.10	11.07	11.85	10.71
H ₂	11.54	8.58	8.65	9.48	10.70	9.79
H ₃	12.13	9.61	10.21	13.90	14.17	12.00
Mean P	12.91	9.93	10.30	12.27	12.91	
	H		P		H*P	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	8.23					
H/P	Pooled					Mean H
	P ₀	P ₁	P ₂	P ₃	P ₄	
H ₀	15.60	12.85	13.51	14.87	15.16	14.40
H ₁	12.76	9.23	9.37	11.28	12.03	10.93
H ₂	11.71	8.87	8.96	9.71	10.89	10.03
H ₃	12.35	9.89	10.48	14.09	14.39	12.24
Mean P	13.10	10.21	10.58	12.49	13.11	
	H		P		H*P	
SE(m) ±	NS		NS		NS	
CD at 5%	NS		NS		NS	
CV (%)	12.75					

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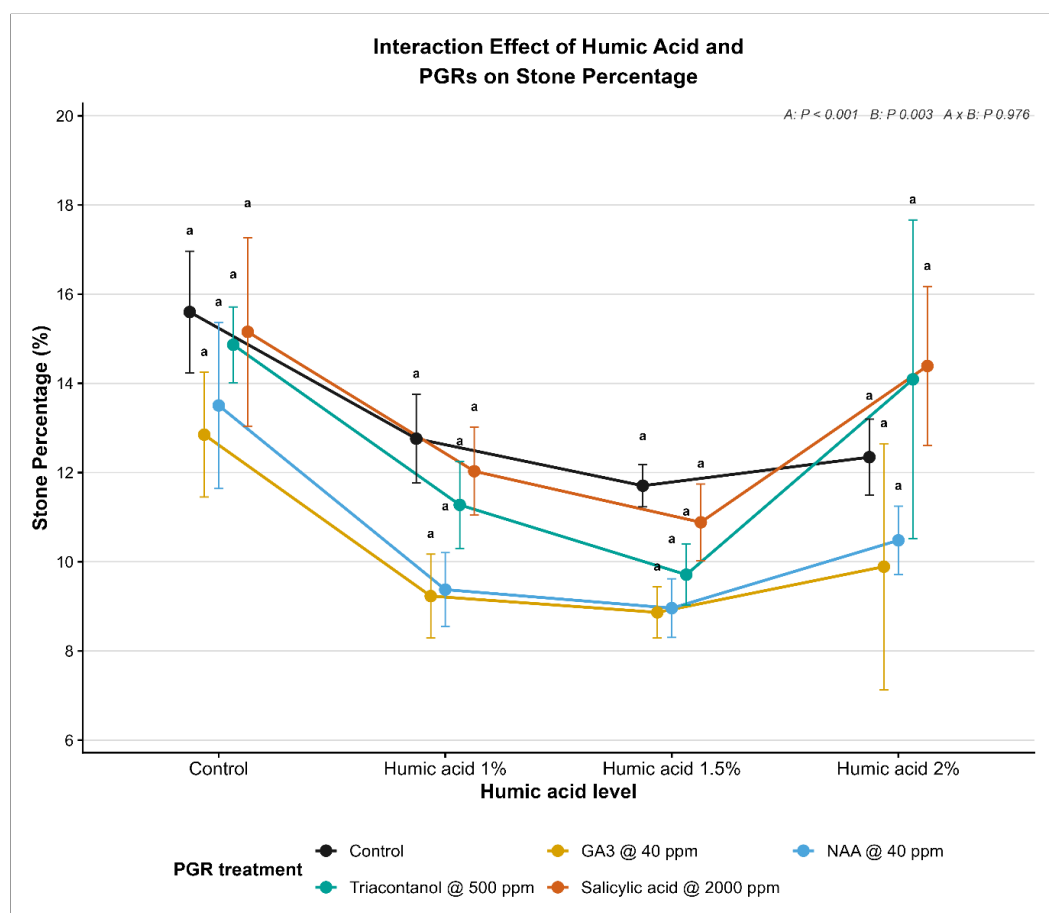


Figure 3. Effect of foliar application of PGR and Humic Acid interaction on Stone percentage in pooled.

Conclusion

The study demonstrated that integrated application of humic acid and plant growth regulators substantially influenced fruit composition and edible fraction of mango cv. Amrapali. Humic acid at 1.5% and GA₃ at 40 ppm were the most effective individual treatments, producing pooled pulp percentages of 75.85 and 75.12%, respectively. Their combined application (H₂P₁) was superior, recording 79.01% pulp, under the untreated combination. In contrast, peel and stone percentages were not significantly affected by treatments. Overall, humic acid 1.5% + GA₃ 40 ppm emerged as the most promising treatment combination for enhancing edible pulp recovery and favourable fruit tissue partitioning in mango cv. Amrapali.

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