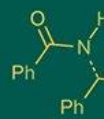


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Flowering phenology, floral biology and fruit biochemical quality of six mango (*Mangifera indica* L.) varieties under the agro-climatic conditions of Chhattisgarh, India

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Abstract

Reliable information on the reproductive behaviour of locally bred mango varieties is a prerequisite for varietal recommendation and for planning breeding programmes, yet such information is scarce for the varieties released in Chhattisgarh. Six mango varieties, comprising five varieties developed at Indira Gandhi Krishi Vishwavidyalaya (Chhattisgarh Swarnaprabha, Chhattisgarh Pawan, Chhattisgarh Achar, Chhattisgarh Raj and Chhattisgarh Gaurav) and the national check Dashehari, were evaluated during 2025-26 at the Horticulture Research Farm, Raipur, in a randomised block design with three replications on sixteen-year-old trees. Observations covered flowering phenology, panicle morphology, floral biology, the successive stages of reproductive attrition, yield and the physical and biochemical quality of ripe fruit. All quantitative traits differed significantly among varieties. Chhattisgarh Raj was consistently the earliest variety, differentiating flower buds on 11 November and reaching harvest maturity on 22 May, twenty-eight days ahead of Dashehari. The interval from fruit set to harvest, however, was almost invariant across varieties, ranging only from 115 to 122 days, so that harvest date was governed almost entirely by flowering date rather than by the duration of fruit growth. Dashehari produced the greatest number of flowers per panicle and the highest proportion of hermaphrodite flowers, whereas Chhattisgarh Raj recorded the widest sex ratio. The proportion of hermaphrodite flowers, and not the absolute number of flowers borne, was closely associated with yield per tree. Chhattisgarh Gaurav combined the highest pulp percentage with the greatest total soluble solids and total sugar content, while Chhattisgarh Achar was the most acidic and the richest in ascorbic acid. The results identify Chhattisgarh Raj for early-season marketing, Chhattisgarh Gaurav for dessert and processing use and Chhattisgarh Achar for pickle preparation.

Keywords: Floral biology, fruit set, heat units, phenology, reproductive attrition, total soluble solids

1. Introduction

Mango (*Mangifera indica* L.), a diploid member of the family Anacardiaceae with $2n = 40$ chromosomes, is the most economically important fruit crop of India and is grown across a wider range of agro-climates than almost any other tropical fruit tree ^[1, 2]. Of the roughly 1500 varieties described in the country, only 25-30 are cultivated commercially, and the remainder constitute a genetic reservoir whose value depends on being adequately characterised ^[3].

Flowering in mango is the physiological bottleneck of the crop. Floral induction is driven by cool inductive temperatures acting on resting terminal shoots, after which apical buds differentiate, panicles emerge and a mixture of male and hermaphrodite flowers opens over several weeks ^[4]. Because only hermaphrodite flowers can set fruit, and because well over ninety percent of the fruitlets that do set are subsequently shed, small differences in floral composition can translate into large differences in yield. The proportion of hermaphrodite flowers, the sex ratio and the timing of the successive phenological events are therefore among the most informative descriptors available for varietal evaluation ^[5, 6]. Chhattisgarh occupies a transitional position between the peninsular and the central Indian mango belts, and ripe fruits become available in the state two to three weeks earlier than in northern India.

Indira Gandhi Krishi Vishwavidyalaya, Raipur, has released several varieties selected from local germplasm — Chhattisgarh Swarnaprabha, Chhattisgarh Pawan, Chhattisgarh Achar, Chhattisgarh Raj and Chhattisgarh Gaurav — but the published information on their reproductive behaviour is limited. An earlier study at the same station described flowering attributes of a partly overlapping set of cultivars under rainfed conditions [7]; it did not, however, follow the crop through to fruit retention, yield and fruit composition, nor did it relate floral traits quantitatively to productivity.

The present investigation was therefore undertaken with three objectives: to characterise the flowering and fruiting phenology of five Chhattisgarh varieties against the national check Dashehari; to quantify the successive stages of reproductive attrition from hermaphrodite flower to harvested fruit; and to determine which floral attributes are associated with yield and how the varieties differ in the physical and biochemical quality of the ripe fruit.

2. Materials and Methods

2.1 Experimental site and weather

The experiment was conducted during 2025-26 at the Horticulture Research Farm, Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh (21.25° N, 81.63° E; 289.15 m above mean sea level). The site lies in the Chhattisgarh Plains agro-climatic zone, which has a dry to moist sub-humid climate and a mean annual rainfall of 1200-1400 mm, about 85% of which falls between the third week of June and mid-September. Weekly meteorological data for the crop period (Fig. 1) were obtained from the agrometeorological observatory located within the farm. One evident transcription error in the record, a weekly mean minimum temperature of 33.37 °C for 15-21 October 2025 in a run of weeks averaging 22-25 °C, was read as 23.37 °C; the week concerned precedes flower bud differentiation in every variety and therefore does not enter any of the heat unit sums reported here.

2.2 Plant material and experimental design

Six varieties were evaluated: Dashehari (V0, national check) and the Indira Gandhi Krishi Vishwavidyalaya releases Chhattisgarh Swarnaprabha (V1), Chhattisgarh Pawan (V2), Chhattisgarh Achar (V3), Chhattisgarh Raj (V4) and Chhattisgarh Gaurav (V5). Uniform, healthy, sixteen-year-old grafted trees free of visible pest and disease damage were selected from the established variety block. The experiment was laid out in a randomised block design with six treatments and three replications, one tree constituting the experimental unit. All trees received identical cultural management: inter-row cultivation with a disc harrow, irrigation by the check-basin system and need-based plant protection with imidacloprid. To avoid interference with pollinators, no insecticide was applied between panicle emergence and the completion of fruit set.

2.3 Phenological observations

Trees were inspected on alternate days from the first week of October 2025 for the onset of visible swelling and morphological change of apical buds, recorded here as flower bud differentiation, and thereafter daily during the anticipated period of panicle emergence. The dates of panicle emergence, initiation of first flowering, opening of

25% and 50% of the flowers, full bloom, first fruit set and first harvest were recorded for each tree. Because calendar dates cannot be analysed directly, each event was expressed as days after 1 October 2025 for statistical analysis and back-transformed to calendar dates for presentation. Growing degree days were accumulated between phenological events using a base temperature of 10 °C and the weekly mean maximum and minimum temperatures of Fig. 1.

2.4 Panicle and floral observations

Ten panicles per tree were tagged at the four cardinal directions of the canopy at a uniform height. Panicle shape and position were classified visually following the mango descriptors of the International Plant Genetic Resources Institute [8]. Panicle length and the breadth at the widest point were measured with a graduated scale and their ratio computed. At full bloom the tagged panicles were detached and the total number of flowers, and separately the number of hermaphrodite flowers, were counted under a hand lens; the number of male flowers was obtained by difference. The percentage of each flower type was computed for each panicle and averaged, and the sex ratio was calculated as the number of male flowers divided by the number of hermaphrodite flowers on the same panicle, the ratios being averaged over panicles.

2.5 Fruit set, retention and yield

Surviving fruitlets on the tagged panicles were counted when they had reached the size of a mustard seed and again at the marble stage (1-2 cm diameter); at each stage the count was expressed as a percentage of the initial number of hermaphrodite flowers on the same panicle. Fruits remaining on the tagged panicles at harvest were recorded as the number retained, and fruit drop was calculated as the percentage decline from initial fruit set to harvest. Fruits were harvested with secateurs, retaining a 5-10 cm pedicel, when they attained harvest maturity as judged by shoulder development and the change in skin lustre. Total yield per tree was recorded on a platform balance.

2.6 Physical fruit characteristics

Ten uniform ripe fruits per tree were used. Fruit shape, surface texture and skin colour at ripening were described using the same descriptor list [8]. Fruit weight was recorded on an electronic balance and fruit volume by water displacement, specific gravity being obtained as the ratio of the two. Fruit length and breadth, peel thickness and stone length and breadth were measured with digital vernier callipers, and the ratios of fruit length to breadth and of stone length to breadth were computed as the fruit shape index and the stone shape ratio respectively. Peel and stone were then removed and weighed, and pulp weight was obtained by subtracting them from the fruit weight, so that the three components sum to the fruit weight by construction. From these weights were computed the pulp, peel and stone percentages, the pulp to stone ratio and the waste index, the last defined here as pulp weight divided by the combined weight of peel and stone, so that a larger value denotes a greater edible fraction.

2.7 Biochemical analysis

Ripe pulp was homogenised and used for all determinations, each performed in triplicate, following standard procedures

for fruit and vegetable products [9]. Total soluble solids were read on a hand refractometer of 0-30 °Brix range at the prevailing room temperature of 28 °C. Titratable acidity was determined by titrating a diluted aliquot of pulp against N/10 sodium hydroxide to a phenolphthalein end point and expressed as percent anhydrous citric acid; the ratio of total soluble solids to acidity was then computed. Ascorbic acid was estimated by titration against 2,6-dichlorophenol-indophenol dye after extraction in 3% metaphosphoric acid and expressed as mg per 100 g of pulp. Reducing sugars were determined volumetrically against Fehling solution with methylene blue as indicator; total sugars were determined in the same way after overnight acid hydrolysis with concentrated hydrochloric acid, and non-reducing sugars were obtained from the difference between total and reducing sugars multiplied by 0.95.

2.8 Statistical analysis

Data were subjected to analysis of variance appropriate to a randomised block design [10]. Treatment effects were tested by the F test and treatment means separated by the critical difference at the 5% level of probability; the standard error of the mean and the critical difference are reported with every table of quantitative data. Percentage data were checked for homogeneity of variance before analysis. All derived quantities — percentages, ratios, differences and heat unit sums — were computed for each replication and then averaged, so that a derived mean may differ slightly from the value obtained by applying the same formula to the tabulated means of its components.

Simple linear correlation coefficients among selected traits were computed on variety means ($n = 6$) and tested by a two-tailed t test. Because eleven coefficients were examined, a Bonferroni-adjusted threshold of $\alpha = 0.0045$ is also reported, and associations that do not clear it are treated as indicative rather than established. Relationships that were significant at the conventional level were additionally checked by the Spearman rank coefficient and by refitting after omission of the check variety, in order to establish that they were not driven by a single observation.

3. Results and Discussion

3.1 Weather during the crop period

The season followed the pattern expected of the Chhattisgarh plains (Fig. 1). Mean weekly minimum temperature fell from about 26 °C in early October to a minimum of 9.6 °C in the second week of December and remained below 18 °C from the second week of December until the end of January, providing a prolonged cool inductive period. The flowering and fruit-development phase from December to April was almost completely dry, with less than 1 mm of rainfall recorded in any week until the last week of April. Maximum temperature rose steeply through March and reached 43.7 °C in the last week of April, coinciding with the marble and mature stages of fruit development in all varieties.

3.2 Flowering and fruiting phenology

Varieties differed markedly in the timing of every phenological event (Table 1). Chhattisgarh Raj was the earliest throughout: it differentiated flower buds on 11 November 2025, forty-one days after the reference date, emerged panicles on 23 November, reached full bloom on 17 January and set its first fruits on 27 January. Dashehari

was the latest to differentiate buds, on 20 December, and the latest to set fruit, on 24 February. The spread between the earliest and latest variety was thirty-nine days for bud differentiation, forty-two days for panicle emergence and twenty-eight days for harvest. Cultivar-dependent differences of this magnitude are well documented in mango and are usually attributed to genotypic differences in the threshold and duration of cool temperature required for floral induction [4, 11, 12].

Expressing the events as intervals rather than dates reveals a pattern that the calendar dates conceal (Table 2). The interval from bud differentiation to panicle emergence was short and fairly uniform, 11-17 days, and the interval from panicle emergence to full bloom was the most variable phase of the reproductive cycle, ranging from 37 days in Dashehari to 59 days in Chhattisgarh Swarnaprabha. In striking contrast, the interval from first fruit set to first harvest was almost invariant: it occupied 115 days in four of the six varieties, 117 days in Chhattisgarh Achar and 122 days in Chhattisgarh Pawan, giving a coefficient of variation of only 2.4% against 20.1% for the panicle emergence to full bloom interval. Accumulated heat units over the same phase were correspondingly conservative, ranging from 2197 to 2493 degree days above a base of 10 °C. The practical implication is direct: in these varieties, harvest date is set almost entirely by the date of flowering and scarcely at all by the duration of fruit growth, so that the date of panicle emergence can be used as an early predictor of harvest date ($r = +0.837$, $p = 0.038$). This relationship is displayed in Fig. 2, in which the fruit-development bars are visibly of near-equal length across varieties while their starting positions differ by up to five weeks.

The twenty-eight day advantage of Chhattisgarh Raj is of commercial significance. Fruits maturing in the third week of May reach the market before the main Dashehari and Langra harvest and command a substantially higher price, and the sequence of maturity from Chhattisgarh Raj on 22 May through Chhattisgarh Swarnaprabha, Chhattisgarh Gaurav and Chhattisgarh Achar to Chhattisgarh Pawan and Dashehari in the third week of June spreads the harvest over four weeks. Comparable extension of the harvest window through varietal choice has been reported from other mango-growing regions [13, 14].

3.3 Panicle morphology

Panicle shape fell into three classes: pyramidal in Dashehari and Chhattisgarh Raj, broadly pyramidal in Chhattisgarh Swarnaprabha and Chhattisgarh Achar, and conical in Chhattisgarh Pawan and Chhattisgarh Gaurav (Table 3). Panicles were terminal in Dashehari, Chhattisgarh Pawan, Chhattisgarh Raj and Chhattisgarh Gaurav and axillary in Chhattisgarh Swarnaprabha and Chhattisgarh Achar. Chhattisgarh Pawan bore the longest (35.77 cm) and broadest (33.43 cm) panicles and Chhattisgarh Raj the shortest (22.57 cm) and narrowest (21.43 cm); the length to breadth ratio was widest in Chhattisgarh Swarnaprabha (1.30) and narrowest in Chhattisgarh Raj (1.04). Panicle length in five of the six varieties fell within the 16.8-33.6 cm range reported for Indian varieties [15], Chhattisgarh Pawan alone exceeding the published upper limit. Notably, panicle size was unrelated to the number of flowers borne ($r = -0.008$ between panicle length and total flowers per panicle), indicating that a large panicle is not by itself an indicator of floral productivity.

3.4 Floral biology

The number of flowers per panicle varied almost twofold, from 902.37 in Chhattisgarh Raj to 1743.67 in Dashehari (Table 3, Fig. 3). Dashehari also bore by far the most hermaphrodite flowers (467.67 per panicle), nearly double the next highest value, whereas Chhattisgarh Swarnaprabha produced the greatest number of male flowers (1428.95). Chhattisgarh Raj was lowest for both counts.

The proportions are more informative than the counts. Hermaphrodite flowers formed 26.81% of the panicle in Dashehari but only 8.82% in Chhattisgarh Raj, and the sex ratio ranged correspondingly from 2.73 to 10.60 (Fig. 4). All differences exceeded the critical difference at the 5% level. Chhattisgarh Swarnaprabha illustrates why the distinction matters: it ranked second for total flowers and first for male flowers, yet its hermaphrodite proportion of 14.54% was the second lowest of the set. Similar cultivar-dependent variation in floral sex expression has been reported repeatedly and is understood to reflect genotype together with the physiological status of the tree and the temperature regime prevailing during panicle development [16, 17, 18].

3.5 Reproductive attrition and fruit retention

Following the tagged panicles from flowering to harvest quantifies the losses that separate floral display from yield (Table 4, Fig. 5). Chhattisgarh Pawan set the greatest number of fruitlets at the mustard stage (81.21 per panicle) and Chhattisgarh Raj the fewest (38.47). Expressed as a percentage of the hermaphrodite flowers available, however, the ranking reverses: Chhattisgarh Pawan converted 52.66% and Chhattisgarh Raj 45.73% of its hermaphrodite flowers into mustard-stage fruitlets, against only 16.23% in Dashehari, which had the largest absolute number of hermaphrodite flowers.

Attrition thereafter was severe in every variety. Between the mustard and marble stages, the number of fruitlets fell by 86-93%, and fruit drop from initial set to harvest ranged from 93.10% in Chhattisgarh Pawan to 98.42% in Chhattisgarh Raj. Only 1.94 to 5.88 fruits per panicle survived to harvest. The logarithmic funnel of Fig. 5 shows that the varieties converge markedly at the later stages: a nearly sixfold range in hermaphrodite flower number is compressed into a threefold range in fruits retained. Heavy and largely genotype-independent fruitlet abscission is characteristic of mango and is generally ascribed to competition among developing fruitlets, embryo abortion and moisture and temperature stress during the post-set period [19, 20]; the steep rise in maximum temperature from March onwards evident in Fig. 1 is consistent with this interpretation.

3.6 Yield

Yield per tree ranged more than sixfold, from 41.15 kg in Chhattisgarh Raj to 266.09 kg in Dashehari, with Chhattisgarh Gaurav (165.59 kg) and Chhattisgarh Pawan (157.01 kg) next (Table 4). The very low yield of Chhattisgarh Raj is the counterpart of its floral biology: the fewest flowers, the smallest hermaphrodite proportion, the widest sex ratio and the highest fruit drop combined to leave fewer than two fruits per panicle at harvest. Its commercial case therefore rests on earliness rather than on productivity, and it is best regarded as a niche variety for early-season marketing or as a parent for earliness in breeding rather than as a general-purpose commercial planting.

3.7 Physical fruit characteristics

Fruit shape was elliptic in four varieties, oblong in Chhattisgarh Swarnaprabha and ovoid in Chhattisgarh Achar; the surface was smooth except in Chhattisgarh Achar and Chhattisgarh Raj, and only Dashehari developed a yellow skin at ripening, the remaining varieties ripening light green to light yellow (Table 5). Chhattisgarh Gaurav produced the largest fruits, with a volume of 354.10 cm³ and a derived weight of 358.22 g, nearly double the 186.46 g of Dashehari. Chhattisgarh Swarnaprabha was distinctive in shape, its length of 17.05 cm and shape index of 2.47 both far exceeding those of the other varieties.

Pulp percentage, the trait of greatest interest to the processing industry, was highest in Chhattisgarh Gaurav (81.54%) and lowest in Chhattisgarh Pawan (69.20%) (Table 6). Chhattisgarh Swarnaprabha recorded the widest pulp to stone ratio (9.55) and the lowest stone percentage (7.92%), whereas Chhattisgarh Raj combined the heaviest stone (46.60 g), the thickest peel (2.90 mm) and the highest stone percentage (14.25%), a combination that limits its recovery of edible pulp. The waste index followed the same pattern, being widest in Chhattisgarh Gaurav (4.46) and narrowest in Chhattisgarh Pawan (2.30). Comparable ranges of pulp recovery among Indian mango varieties have been reported previously [21, 22].

3.8 Biochemical fruit quality

The varieties separated sharply on composition (Table 7, Fig. 6). Chhattisgarh Gaurav accumulated the most total soluble solids (22.83 °Brix) and the most total sugars (20.47%), of which the greater part was non-reducing (14.51%), whereas Chhattisgarh Achar was lowest for both (13.31 °Brix and 10.34%). Titratable acidity showed the reverse ordering, being highest in Chhattisgarh Achar (0.81%) and lowest in Dashehari (0.22%). Because the ratio of total soluble solids to acidity integrates both, it produced the widest separation of any trait measured, ranging from 16.51 in Chhattisgarh Achar to 77.69 in Dashehari.

Ascorbic acid ranged from 29.29 mg per 100 g in Dashehari to 40.78 mg per 100 g in Chhattisgarh Achar and was positively associated with acidity ($r = +0.835$, $p = 0.039$), an association consistent with the shared dependence of organic acid and ascorbate pools on the stage of ripening at which the fruit is sampled. Total soluble solids and total sugars were, as expected, very closely correlated ($r = +0.979$, $p = 0.0007$), confirming that soluble solids in these varieties are largely accounted for by sugars and that the refractometric reading is an adequate proxy for sugar content in routine varietal screening.

These differences translate directly into recommended end uses. Chhattisgarh Gaurav, with the highest pulp percentage, the highest soluble solids and the highest sugar content, is the most suitable of the set for dessert consumption and for pulp processing. Chhattisgarh Achar, whose name reflects its traditional use, is confirmed as a pickling variety: high acidity, high ascorbic acid, low sugars and the narrowest soluble solids to acid ratio are precisely the attributes sought for that purpose, and comparable compositional profiles have been used elsewhere to allocate genotypes between table and processing use [23, 24].

3.9 Relationships among traits

Correlations computed on variety means (Table 8) clarify which floral attributes actually matter for productivity. The

number of flowers borne per panicle was not significantly associated with yield ($r = + 0.579$, $p = 0.229$), nor was the number of male flowers ($r = + 0.361$). The percentage of hermaphrodite flowers, by contrast, was very closely and positively associated with yield ($r = + 0.984$, $p = 0.0004$), and the sex ratio negatively so ($r = -0.941$, $p = 0.0052$); both relationships are shown in Fig. 7. The rank correlation between hermaphrodite percentage and yield was also significant ($p = + 0.943$, $p = 0.005$) and the relationship persisted when the outlying check variety Dashehari was excluded ($r = + 0.976$, $p = 0.004$), indicating that it is not an artefact of a single observation.

The absolute number of hermaphrodite flowers was a weaker predictor ($r = + 0.874$ overall but $r = + 0.632$ and non-significant when Dashehari was excluded), so it is the proportion rather than the count that carries the signal. This finding gives quantitative support to a proposition that is often asserted in varietal evaluation but seldom tested, namely that a narrow sex ratio is the more useful selection criterion, and it suggests that hermaphrodite percentage measured at full bloom could serve as an early indicator of productivity in screening large numbers of seedling progenies. Given that only six varieties were compared in a single season, the relationship should be regarded as

promising rather than established, and confirmation on a larger and independent set of genotypes is required.

3.10 Limitations

Three constraints bound the inferences drawn above. First, the data derive from a single fruiting season at a single location, and mango is strongly alternate bearing, so the yields reported here — and to a lesser extent the floral counts, which respond to the previous season's crop load — may not be reproduced in an off year. Second, yield is expressed per tree and has not been adjusted for canopy volume; although all trees were of the same age and received identical management, varietal differences in vigour could contribute to the yield ranking independently of floral biology, and the association between hermaphrodite percentage and yield should therefore be regarded as consistent with, but not proof of, a causal role. Third, the correlations rest on six variety means, which limits both the precision of the coefficients and the number of hypotheses that can properly be tested; only two of the eleven coefficients survive adjustment for multiple comparisons. Repetition over at least three successive seasons, at more than one site, and with yield expressed per unit canopy volume would address all three.

Table 1: Flowering and fruiting phenology of six mango varieties, Raipur, 2025–26

Code	Variety	Bud diff.	Panicle emerg.	First flower	25 % bloom	50 % bloom	Full bloom	First fruit set	Harvest
V0	Dashehari	20 Dec 2025	4 Jan 2026	9 Jan 2026	20 Jan 2026	30 Jan 2026	10 Feb 2026	24 Feb 2026	19 Jun 2026
V1	Ch. Swarnaprabha	19 Nov 2025	4 Dec 2025	12 Dec 2025	4 Jan 2026	16 Jan 2026	1 Feb 2026	12 Feb 2026	7 Jun 2026
V2	Ch. Pawan	3 Dec 2025	15 Dec 2025	23 Dec 2025	16 Jan 2026	23 Jan 2026	7 Feb 2026	16 Feb 2026	18 Jun 2026
V3	Ch. Achar	6 Dec 2025	23 Dec 2025	31 Dec 2025	12 Jan 2026	28 Jan 2026	2 Feb 2026	18 Feb 2026	15 Jun 2026
V4	Ch. Raj	11 Nov 2025	23 Nov 2025	11 Dec 2025	26 Dec 2025	3 Jan 2026	17 Jan 2026	27 Jan 2026	22 May 2026
V5	Ch. Gaurav	19 Dec 2025	30 Dec 2025	8 Jan 2026	18 Jan 2026	3 Feb 2026	7 Feb 2026	17 Feb 2026	12 Jun 2026

Dates are means of three replications; observations were recorded on alternate days for bud differentiation and daily thereafter. For analysis of variance each date was converted to days after 1 October 2025 (see Table 2).

Table 2: Derived phenological intervals and accumulated heat units of six mango varieties

Variety	Bud diff. (DAO)	Harvest (DAO)	Bud diff. → panicle emerg. (d)	Panicle emerg. → full bloom (d)	Full bloom → fruit set (d)	Fruit set → harvest (d)	GDD fruit set → harvest (°C d)
Dashehari	80	261	15	37	14	115	2391
Ch. Swarnaprabha	49	249	15	59	11	115	2303
Ch. Pawan	63	260	12	54	9	122	2493
Ch. Achar	66	257	17	41	16	117	2400
Ch. Raj	41	233	12	55	10	115	2197
Ch. Gaurav	79	254	11	39	10	115	2348
Mean	63.0	252.3	13.7	47.5	11.7	116.5	2356
Range	41–80	233–261	11–17	37–59	9–16	115–122	2197–2493
CV (%)	—	—	17.1	20.1	23.4	2.4	4.3

DAO, days after 1 October 2025. GDD, growing degree days accumulated above a base temperature of 10 °C from the weekly mean maximum and minimum temperatures of Fig. 1. Note the small coefficient of variation of the fruit set to harvest interval relative to all earlier phases.

Table 3: Panicle morphology and floral biology of six mango varieties

Variety	Panicle shape	Panicle position	Panicle length (cm)	Panicle breadth (cm)	L : B ratio	Total flowers panicle ⁻¹	Male flowers panicle ⁻¹	Hermaph. flowers panicle ⁻¹	Male flowers (%)	Hermaph. flowers (%)	Sex ratio
Dashehari	Pyramidal	Terminal	29.40	24.73	1.18	1743.67	1276.57	467.67	73.18	26.81	2.73
Ch. Swarnaprabha	Broadly pyramidal	Axillary	29.33	22.43	1.30	1671.35	1428.95	243.31	85.45	14.54	5.88
Ch. Pawan	Conical	Terminal	35.77	33.43	1.06	1002.08	847.30	155.94	84.54	15.45	5.55
Ch. Achar	Broadly pyramidal	Axillary	27.80	22.17	1.25	1272.33	1061.67	210.67	83.44	16.55	5.15
Ch. Raj	Pyramidal	Terminal	22.57	21.43	1.04	902.37	822.33	79.67	91.17	8.82	10.60
Ch. Gaurav	Conical	Terminal	33.60	30.30	1.10	1073.94	885.47	188.38	82.47	17.53	4.72
SEm ±	—	—	0.63	0.44	0.03	8.76	9.57	11.94	0.97	0.97	0.63
CD (5 %)	—	—	2.00	1.37	0.09	27.60	25.84	37.63	3.05	3.05	1.99

Means of ten tagged panicles per tree in three replications. Sex ratio and the two percentages were computed for each panicle and then averaged, so they do not reproduce exactly from the tabulated flower counts. Panicle shape and position follow the descriptor list of the International Plant Genetic Resources Institute [8].

Table 4: Reproductive attrition, fruit retention and yield of six mango varieties

Variety	Fruits at mustard stage (no.)	Fruit set at mustard stage (%)	Fruits at marble stage (no.)	Fruit set at marble stage (%)	Fruits retained at harvest (no.)	Fruit drop (%)	Yield (kg tree ⁻¹)
Dashehari	76.96	16.23	5.39	1.15	4.90	94.87	266.09
Ch. Swarnaprabha	59.51	24.52	4.66	1.91	3.43	96.47	113.41
Ch. Pawan	81.21	52.66	11.35	7.34	5.88	93.10	157.01
Ch. Achar	67.55	35.70	7.03	3.14	4.41	95.14	152.35
Ch. Raj	38.47	45.73	4.06	5.14	1.94	98.42	41.15
Ch. Gaurav	71.53	38.09	6.74	3.58	2.82	96.85	165.59
SEm ±	1.38	1.46	0.34	0.24	0.07	0.33	1.56
CD (5 %)	4.35	4.61	1.08	0.74	0.21	1.05	4.90

Counts are per tagged panicle. Percentage fruit set is expressed on the number of hermaphrodite flowers initially borne on the same panicle and was computed panicle-wise before averaging. Fruit drop is the percentage decline between the number of fruitlets present at initial fruit set, which precedes the mustard stage and is not tabulated here, and the number retained at harvest; it is therefore not reproducible from the columns shown.

Table 5: Physical characteristics of ripe fruits of six mango varieties

Variety	Fruit shape	Fruit surface	Skin colour (ripe)	Fruit volume (cm ³)	Specific gravity (g cm ⁻³)	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Shape index
Dashehari	Elliptic	Smooth	Yellow	175.22	1.02	186.46	11.01	6.55	1.70
Ch. Swarnaprabha	Oblong	Smooth	Light green	314.26	1.07	323.03	17.05	6.86	2.47
Ch. Pawan	Elliptic	Smooth	Light green	233.66	1.08	252.92	10.48	6.71	1.56
Ch. Achar	Ovoid	Rough	Light green	286.89	1.09	316.83	10.89	7.47	1.45
Ch. Raj	Elliptic	Rough	Light green	304.26	1.07	326.64	10.98	5.55	1.97
Ch. Gaurav	Elliptic	Smooth	Light yellow	354.10	1.01	358.22	11.25	7.79	1.44
SEm ±	—	—	—	3.44	0.01	—	0.31	0.19	0.05
CD (5 %)	—	—	—	10.85	0.02	—	0.98	0.61	0.16

Fruit weight was recorded directly on an electronic balance; because pulp weight was obtained by difference, it equals the sum of the pulp, peel and stone weights of Table 6. It agreed with the product of fruit volume and specific gravity to within 5 % in all varieties, the residual reflecting the rounding of specific gravity to two decimal places.

Table 6: Pulp, peel and stone characteristics of ripe fruits of six mango varieties

Variety	Pulp weight (g)	Peel weight (g)	Stone weight (g)	Peel thickness (mm)	Stone length (cm)	Stone breadth (cm)	Pulp (%)	Peel (%)	Stone (%)	Pulp : stone ratio
Dashehari	136.68	24.45	25.33	2.04	8.55	2.43	73.30	12.86	13.90	5.40
Ch. Swarnaprabha	253.70	42.71	26.62	2.41	11.73	3.60	78.50	13.17	7.92	9.55
Ch. Pawan	176.21	43.34	33.37	2.45	9.40	2.62	69.20	16.28	12.99	5.28
Ch. Achar	245.35	34.75	36.73	1.89	7.77	3.56	78.38	11.13	11.42	6.68
Ch. Raj	249.13	30.91	46.60	2.90	8.28	4.55	75.49	9.63	14.25	5.34
Ch. Gaurav	292.72	32.91	32.59	2.20	8.46	3.61	81.54	9.41	8.95	8.98
SEm ±	0.59	0.98	0.78	0.03	0.19	0.19	0.51	0.33	0.25	0.18
CD (5 %)	1.85	3.09	2.44	0.10	0.58	0.60	1.60	1.05	0.80	0.57

Waste index, computed as pulp weight divided by the combined weight of peel and stone, was 2.74, 3.66, 2.30, 3.43, 3.21 and 4.46 for V0 to V5 respectively (SEm ± 0.06; CD 5 % = 0.18); on this definition a larger value denotes a greater edible fraction, which is the inverse of the sense in which the term is sometimes used. Percentages were computed replication-wise before averaging and therefore need not sum to exactly 100.

Table 7: Biochemical quality of ripe fruits of six mango varieties

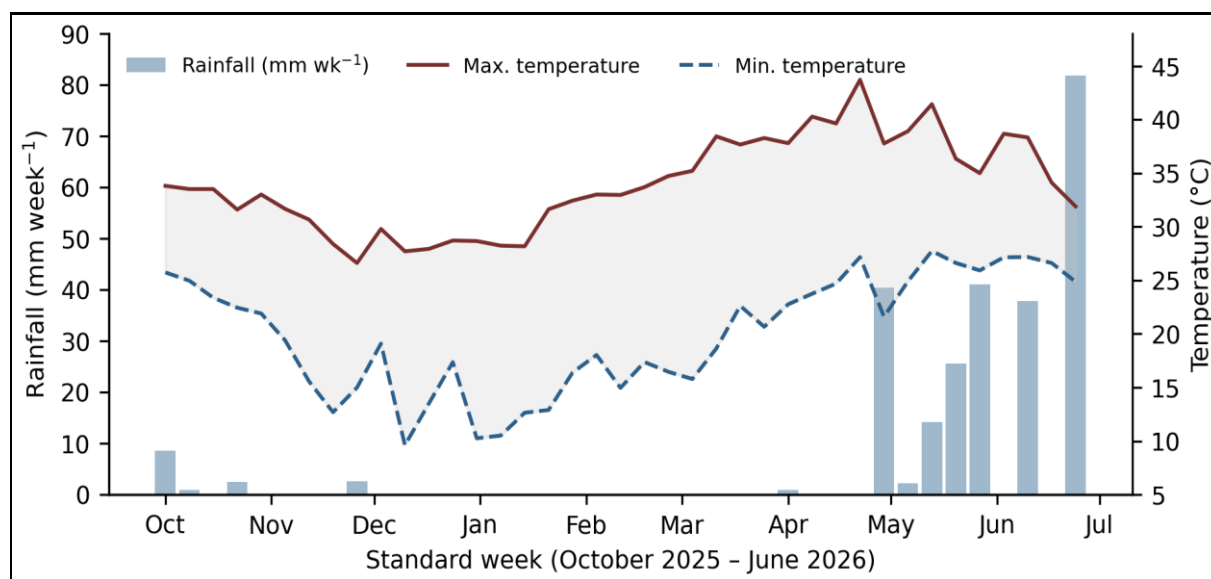
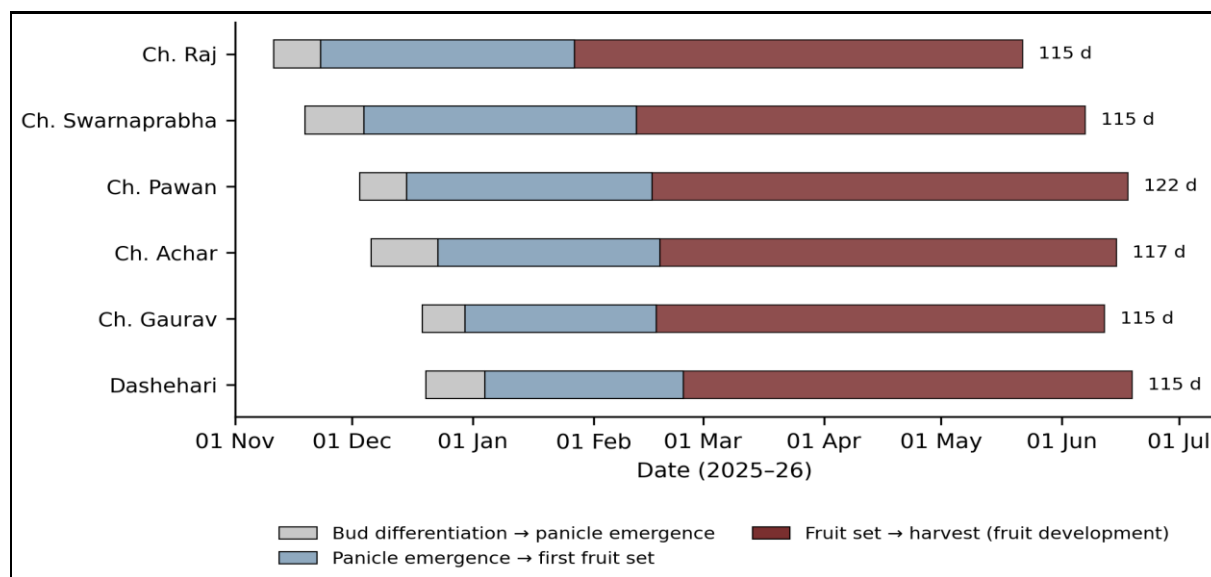
Variety	TSS (°Brix)	Titrateable acidity (%)	Ascorbic acid (mg 100 g ⁻¹)	TSS : acid ratio	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
Dashehari	17.34	0.22	29.29	77.69	15.53	5.06	10.61
Ch. Swarnaprabha	18.52	0.50	33.34	37.31	17.22	3.46	13.51
Ch. Pawan	16.56	0.37	29.72	45.10	15.26	4.45	10.57
Ch. Achar	13.31	0.81	40.78	16.51	10.34	2.70	7.50
Ch. Raj	17.62	0.41	34.61	42.73	15.07	4.45	10.30
Ch. Gaurav	22.83	0.41	37.47	56.15	20.47	5.60	14.51
SEm ±	0.19	0.02	0.29	0.86	0.17	0.06	0.22
CD (5 %)	0.59	0.06	0.92	2.72	0.53	0.20	0.69

TSS, total soluble solids, read at an ambient temperature of 28 °C without correction to 20 °C. Titrateable acidity is expressed as per cent anhydrous citric acid. Each value is the mean of three replications, each determined in triplicate; the ratio and the non-reducing sugar fraction were computed replication-wise before averaging.

Table 8: Simple correlation coefficients among selected reproductive, yield and quality traits of six mango varieties

Trait 1	Trait 2	r	p	Significance
Hermaphrodite flowers (%)	Yield per tree	+0.984	0.0004	**
Sex ratio	Yield per tree	-0.941	0.0052	**
Hermaphrodite flowers (no.)	Yield per tree	+0.874	0.0229	*
Total flowers per panicle	Yield per tree	+0.579	0.2290	ns
Male flowers per panicle	Yield per tree	+0.361	0.4819	ns
Fruits at mustard stage (no.)	Yield per tree	+0.832	0.0399	*
Date of panicle emergence	Date of harvest	+0.837	0.0375	*
Panicle length	Total flowers per panicle	-0.008	0.9878	ns
Total soluble solids	Total sugars	+0.979	0.0007	**
Titrateable acidity	Ascorbic acid	+0.835	0.0385	*
Pulp percentage	Pulp : stone ratio	+0.789	0.0620	ns

Correlations were computed on variety means ($n = 6$) and tested by a two-tailed t test. * $p < 0.01$; $p < 0.05$; ns, not significant. Under a Bonferroni adjustment for the eleven coefficients examined ($\alpha = 0.0045$), only the associations of hermaphrodite percentage with yield and of total soluble solids with total sugars remain significant; the remainder should be read as indicative. The association between hermaphrodite percentage and yield was confirmed by the Spearman rank coefficient ($\rho = +0.943$, $p = 0.005$) and persisted when Dashehari was excluded ($r = +0.976$, $p = 0.004$).

**Fig 1:** Weekly meteorological conditions at Raipur during the experimental period, October 2025 to June 2026**Fig 2:** Phenological timeline of six mango varieties, showing the near-constant duration of fruit development (115–122 days) against widely differing dates of flowering

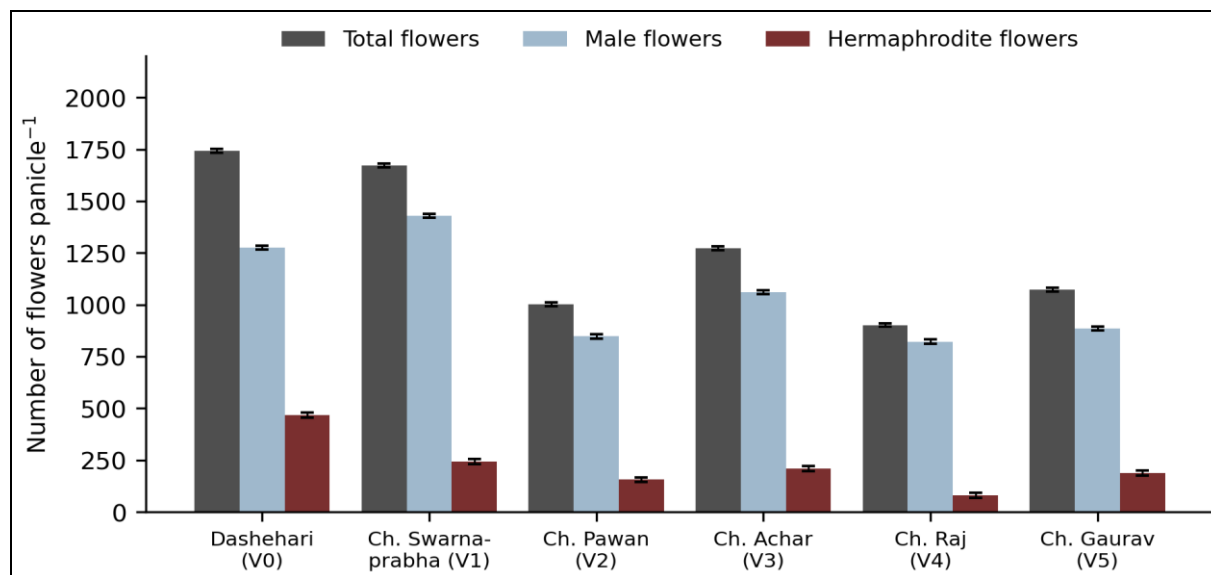


Fig 3: Total, male and hermaphrodite flowers per panicle in six mango varieties. Bars are means and whiskers the standard error of the mean; CD (5 %) = 27.60, 25.84 and 37.63 for total, male and hermaphrodite flowers respectively

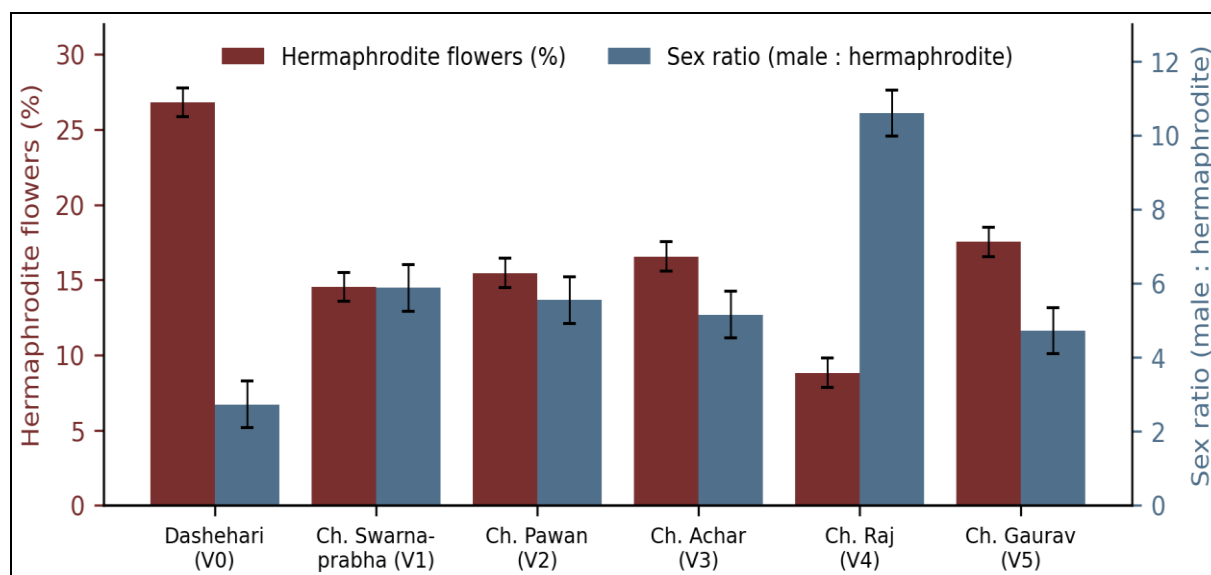


Fig 4: Percentage of hermaphrodite flowers and sex ratio of six mango varieties

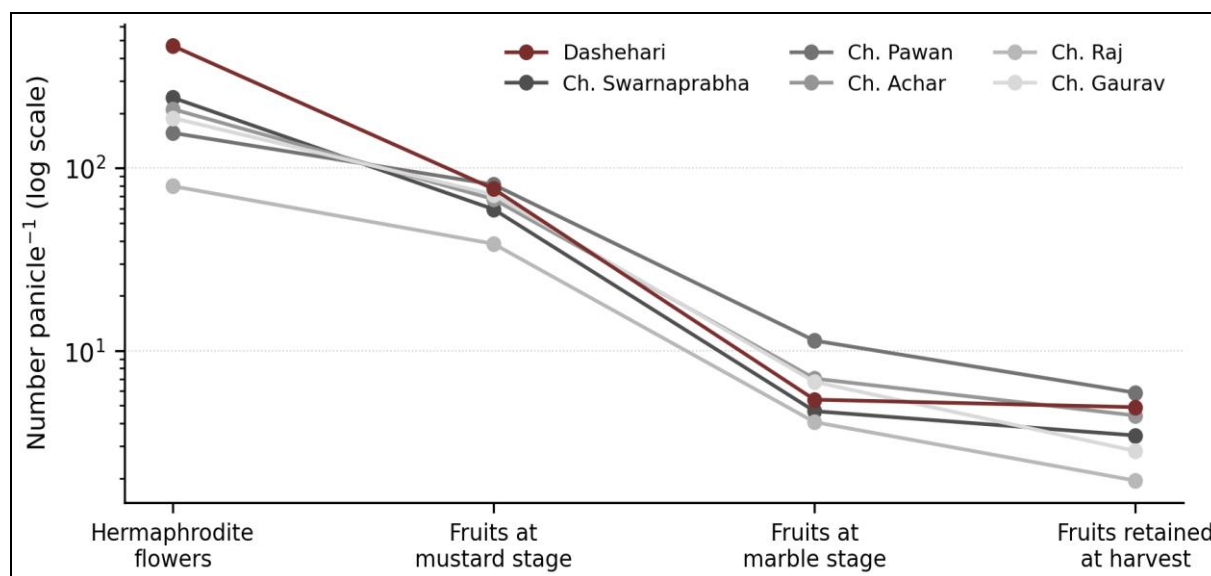


Fig 5: Reproductive attrition from hermaphrodite flower to harvested fruit in six mango varieties (logarithmic scale)

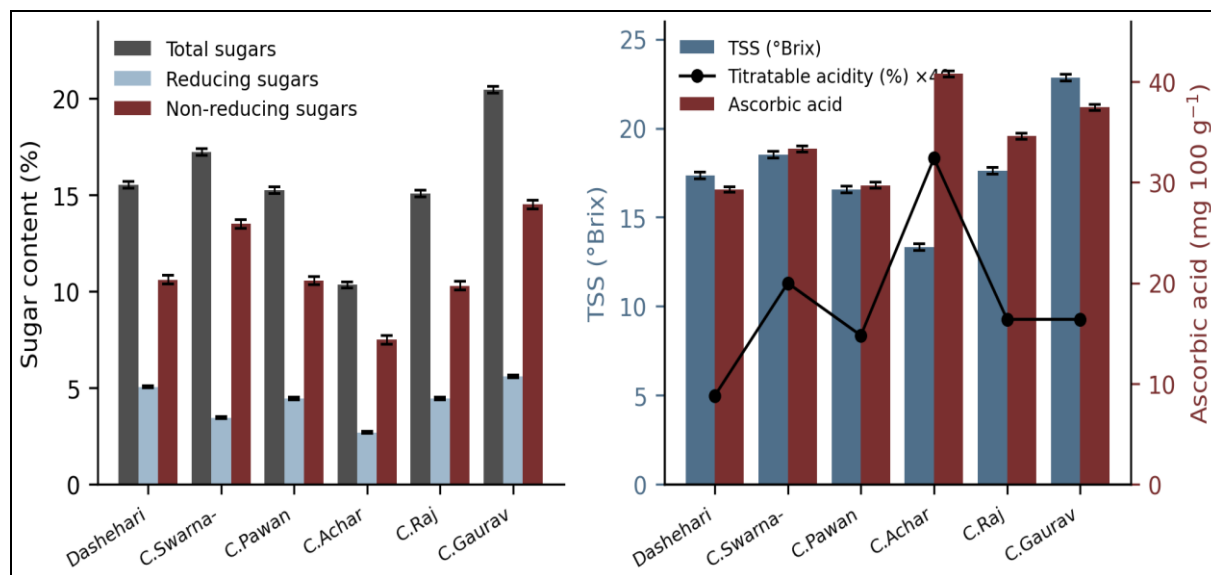


Fig 6: Sugar fractions (left) and total soluble solids, ascorbic acid and titratable acidity (right) of ripe fruits of six mango varieties

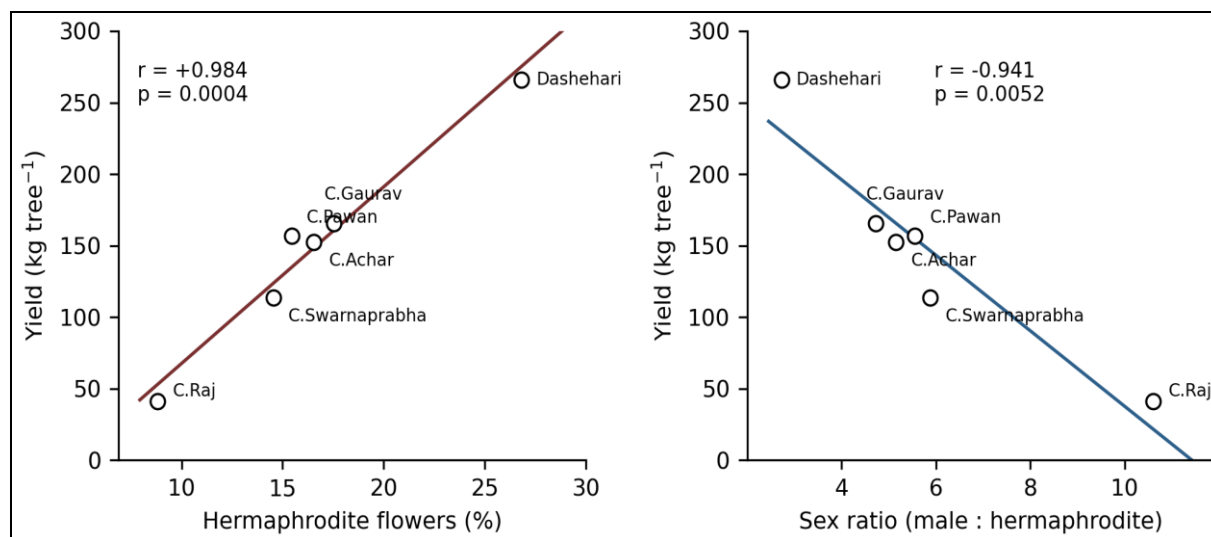


Fig 7: Relationship between the percentage of hermaphrodite flowers (left) and the sex ratio (right) and yield per tree in six mango varieties

4. Conclusion

Substantial and statistically significant variation was found among the six varieties for every quantitative trait examined. Chhattisgarh Raj is confirmed as a distinctly early variety, reaching harvest maturity twenty-eight days ahead of Dashehari, but its narrow floral base and severe fruit drop restrict it to niche early-season production or to use as a donor of earliness in breeding. Chhattisgarh Gaurav emerges as the most promising variety for general cultivation, combining a high pulp percentage with the highest soluble solids and sugar content and a yield second only to the check. Chhattisgarh Achar is confirmed as a processing type for pickle preparation. Two findings have wider relevance: the duration of fruit development was almost constant across varieties at 115-122 days, so that harvest date is determined by flowering date and can be predicted from the date of panicle emergence; and the proportion, rather than the number, of hermaphrodite flowers was closely associated with yield. Because these conclusions rest on a single season at one location, multi-season and multi-location evaluation is required before they are used as a basis for varietal recommendation, and the

alternate-bearing habit of mango makes repetition over at least three successive years particularly important.

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6. Author contributions

MT conducted the field and laboratory investigation, curated the data and prepared the original draft. GLS conceived and supervised the study and revised the manuscript. HKP and GG contributed to the experimental design and the interpretation of the fruit quality data. VB and RY assisted with field observations and statistical analysis. All authors read and approved the final manuscript.

7. Conflict of Interest

The authors declare that they have no conflict of interest.

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