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Assessment of growth variation among indigenous germplasm of turmeric (*Curcuma longa* L.)

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Abstract

Turmeric (*Curcuma longa* L.) is a clonally propagated rhizomatous crop in which phenotypic characterization of germplasm is fundamental to the identification of useful parents and locally adapted material. The present study assessed growth and phenological variation among 54 indigenous turmeric accessions, including the national and local checks Roma, Suranjana, BSR-2, Chhattisgarh Haldi-1 (IT-2), Chhattisgarh Haldi-2 (IT-10), and CG Raigarh Haldi-3 (IT-36), evaluated in a randomized complete block design with two replications during Kharif 2021-22 and 2022-23 at the Research Farm of AICRP on Spices, CARS, Raigarh, Chhattisgarh. Five traits were analyzed from the supplied observations: days to maturity, plant height, number of shoots, number of leaves on main shoots, and petiole length. Large accession-level differences were evident in pooled means. Days to maturity ranged from 197.75 days in IT-1 to 243.50 days in IT-43, whereas plant height ranged from 74.71 to 134.79 cm. Number of shoots varied from 2.04 to 6.16, leaves on main shoots from 4.01 to 9.08, and petiole length from 11.39 to 35.18 cm. IT-1 was the most vigorous accession across the four structural growth traits and was also the earliest accession, while IT-43 showed the contrasting combination of late maturity and low vegetative expression. Accession-level pooled correlations were exceptionally strong: maturity was negatively associated with plant height ($r = -0.989$), shoots ($r = -0.994$), leaves ($r = -0.992$), and petiole length ($r = -0.984$), while the four vegetative traits were positively interrelated ($r = 0.993-0.996$). Seasonal means were highly consistent, with year-to-year correlations of 0.907-0.991 across traits. The supplied pooled critical differences (5%) ranged from 0.36 to 7.81 in trait-specific units, supporting clear separation among several contrasting accessions. Overall, the dataset demonstrates substantial and internally coherent growth variation within the Raigarh germplasm collection, identifying IT-1 and a closely related high-growth group as promising sources for further agronomic evaluation and breeding, while the low-growth/late-maturing group provides contrasting material for diversity-based selection. Because yield and quality traits were not included in the present dataset, conclusions are restricted to growth and maturity attributes.

Keywords: *Curcuma longa*; turmeric germplasm; growth variation; plant height; vegetative traits; days to maturity; genetic resources

Introduction

Turmeric (*Curcuma longa* L.) is an economically important rhizomatous species of the family Zingiberaceae and is widely cultivated in tropical and subtropical production systems. Its value is associated with culinary use, natural colour, medicinal applications, and the accumulation of curcuminoids and volatile constituents. For a vegetatively propagated crop, germplasm collections are particularly important because useful variability has to be identified and conserved within clonally maintained material. Consequently, systematic phenotypic characterization remains an essential first step before advanced breeding, molecular characterization, or targeted multi-location evaluation. Indian turmeric germplasm has repeatedly shown substantial morphological and genetic diversity. Roy *et al.* (2011) [10], while evaluating 83 accessions from north-eastern India, reported useful variation in quantitative characters and demonstrated that multivariate methods could separate accessions on the basis of morphological traits. Mishra *et al.* (2015) [8] likewise documented considerable natural and genetic variability among 65 turmeric germplasms and reported high heritability for plant height. Gupta *et al.* (2015) [5] further demonstrated considerable genetic divergence among 65 genotypes using 13 agro-morphological characters,

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with plant height. Among the major contributors to divergence. These findings establish that growth architecture is not merely descriptive: it can serve as an informative component of germplasm differentiation.

More recent studies continue to support the value of growth traits in turmeric characterization. Anindita *et al.* (2020)^[1] reported broad phenotypic diversity in Indonesian local turmeric accessions and specifically identified plant height, number of shoots, number of leaves on the main shoot, and petiole length among the traits that distinguished accessions. This combination is especially relevant to the present study because the same four structural traits are available in the supplied Raigarh dataset. Similarly, Deve and Sharma (2022)^[3] reported wide variability among turmeric genotypes, while Patel *et al.* (2023)^[9] showed significant variability for growth and maturity-related characters in Indian germplasm and highlighted the usefulness of conventional phenotypic characterization alongside molecular diversity analysis.

Current evidence also indicates that phenotypic characterization is increasingly being integrated with multivariate and molecular approaches. Verma *et al.* (2015)^[12] found substantial molecular diversity among indigenous Indian turmeric genotypes, with high polymorphism and broad genetic distances. Dudekula *et al.* (2022)^[4] used rhizome yield traits and curcuminoid profiles to resolve genetic diversity among Indian turmeric germplasm, reinforcing the concept that diverse phenotypes can provide a valuable entry point for more detailed selection. Most recently, Das *et al.* (2026)^[2] demonstrated substantial variability for plant height and related traits across turmeric genotypes and emphasized the role of growth characters in integrated selection. Thus, a well-documented regional collection can contribute to

breeding not only by identifying immediately vigorous accessions but also by preserving contrasting phenotypes for future trait-specific selection. The present dataset originates from the AICRP on Spices, CARS, Raigarh, and Chhattisgarh and comprises 54 indigenous accessions evaluated for days to maturity and four vegetative growth attributes over two seasons. Although the source document contains only these growth-related observations, it offers an unusually coherent opportunity to examine the magnitude, direction, and stability of phenotypic variation. The study therefore focuses specifically on (i) quantifying accession-wise variation in maturity and vegetative growth, (ii) identifying contrasting accessions based on pooled performance, (iii) comparing the consistency of trait expression between the two seasons, and (iv) examining accession-level interrelationships among the recorded traits. Importantly, the study does not infer rhizome yield or quality performance because those variables are not part of the supplied dataset.

3. Materials and Methods

3.1 Experimental site and genetic material

The experiment was conducted at the Research Farm of AICRP on Spices, College of Agriculture and Research Station (CARS), Raigarh, Chhattisgarh, India. The crop was turmeric (*Curcuma longa* L.). The material comprised 54 indigenous accessions, including the checks Roma, Suranjana, and BSR-2, together with the named Chhattisgarh materials Chhattisgarh Haldi-1 (IT-2), Chhattisgarh Haldi-2 (IT-10), and CG Raigarh Haldi-3 (IT-36). The source document does not provide soil analytical values, coordinates, rainfall, temperature, or other site-specific environmental measurements; these were therefore not added to the present manuscript.

Table 1: Experimental framework reported in the supplied document

Component	Description
Crop	Turmeric (<i>Curcuma longa</i> L.)
Number of accessions	54
Replications	02
Experimental design	Randomized complete block design (RCBD)
Seasons	Kharif 2021-22 and Kharif 2022-23
Spacing	30 cm × 20 cm
Plot size	3 m × 1 m
Location	Research Farm of AICRP on Spices, CARS, Raigarh (C.G.)
Cultural practice	Recommended cultural package for late-sown turmeric, as stated in source document

The experimental structure therefore provided replicated evaluation across two consecutive *Kharif* seasons. Each accession was represented in the RBD with two replications, and the same spacing and plot dimensions were used. The use of two seasons is

important for distinguishing persistent accession differences from season-specific shifts in mean expression.

3.2 Traits recorded

Table 2: Growth and maturity traits included in the supplied dataset

Trait	Unit	Interpretive role
Days to maturity	days	Phenological duration
Plant height	cm	Vegetative stature
Number of shoots	number	Shoot multiplication/plant architecture
Leaves on main shoots	number	Leaf-bearing capacity of the main shoot
Petiole length	cm	Leaf structural dimension

The source document provides accession means for each season and a pooled mean, together with SEM ($\pm$), critical difference (CD) at 5%, and coefficient of variation (CV) for each trait. No individual-plant observations or replication-level raw observations are available in the supplied file. Accordingly, all secondary analyses in this article are based on the reported accession means and pooled values; they should be interpreted as

accession-level phenotypic analyses rather than estimates of genotypic variance components.

3.3 Statistical analysis

The source tables report SEM ($\pm$), CD at the 5% probability level, and CV for each season and for pooled data. These supplied inferential statistics were retained without modification. For

additional descriptive analysis, minimum, maximum, range, arithmetic mean, sample standard deviation, and descriptive coefficient of variation were calculated from the 54 reported pooled accession means for each trait. Seasonal means were calculated across the 54 accession means for each year, and Pearson correlation coefficients were calculated among pooled accession means for the five recorded traits. Pearson correlations were also calculated between the two seasonal accession means for each trait as a descriptive indicator of cross-season consistency. Because the source file does not report genotype $\times$ environment interaction statistics, F-values, variance components, heritability, genetic advance, or replication-level residual data, none of these parameters was reconstructed or inferred. Likewise, no artificial observations were generated to

fill the missing analytical levels. This conservative approach preserves the evidentiary boundary of the supplied dataset.

4. Results

4.1 Overall magnitude of variation

The 54-accession collection expressed a wide phenotypic spectrum across all five recorded traits (Table 3). Among the pooled means, days to maturity ranged from 197.75 to 243.50 days, a spread of 45.75 days. Plant height varied from 74.71 to 134.79 cm, a 60.08 cm difference between the minimum and maximum accessions. Number of shoots ranged from 2.04 to 6.16, while leaves on main shoots ranged from 4.01 to 9.08. Petiole length showed the broadest proportional spread, from 11.39 to 35.18 cm.

Table 3: Descriptive statistics of pooled accession means for the five traits (n = 54)

Trait	Minimum	Maximum	Range	Mean	SD	CV (%)	Minimum accession	Maximum accession
Days to maturity	197.75	243.50	45.75	222.42	9.96	4.48	IT-1	IT-43
Plant height (cm)	74.71	134.79	60.08	104.89	16.79	16.00	IT-43	IT-1
Number of shoots	2.04	6.16	4.12	4.00	1.07	26.89	IT-43	IT-1
Leaves on main shoots	4.01	9.08	5.07	6.55	1.34	20.54	IT-43	IT-1
Petiole length (cm)	11.39	35.18	23.79	23.19	7.21	31.08	IT-43	IT-1

The pattern was biologically coherent across the four structural growth traits. IT-1 occupied the maximum position for plant height, shoot number, leaf number, and petiole length, whereas IT-43 occupied the minimum position for all four. Conversely,

IT-1 was the earliest accession for maturity and IT-43 was the latest. Thus, the extremes of the dataset were not randomly distributed across traits; they represented strongly contrasting plant architectures.

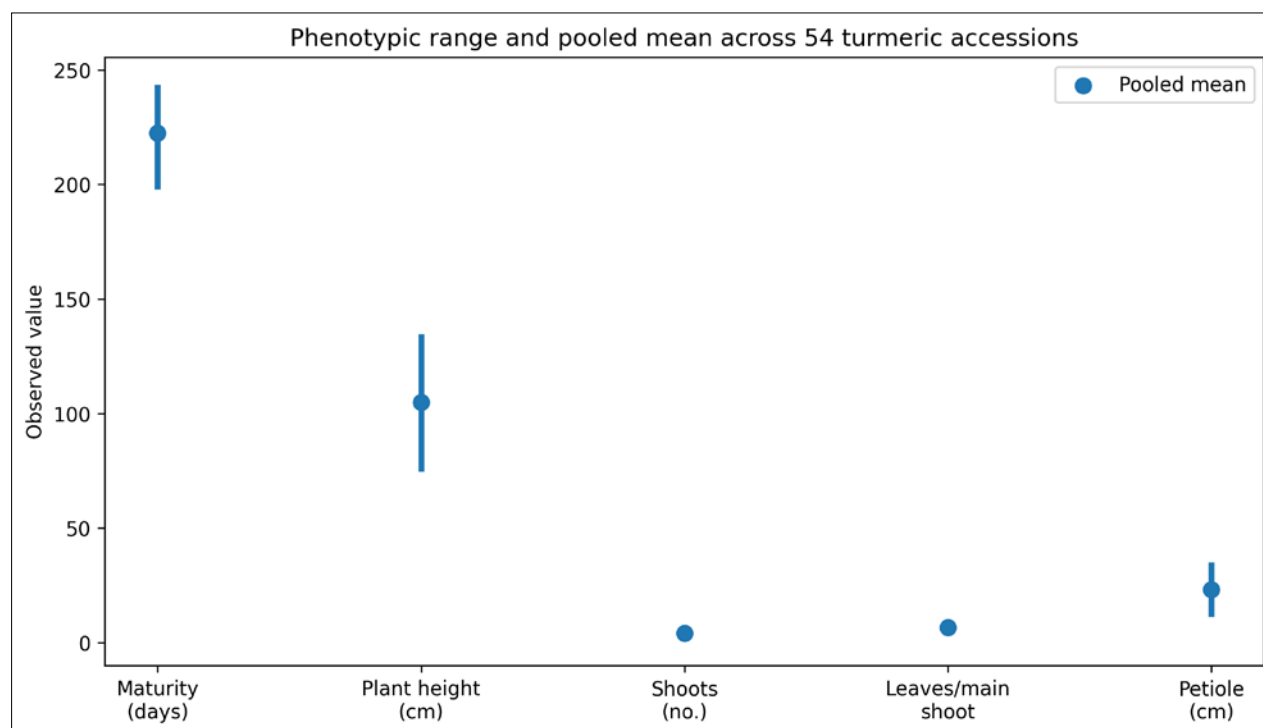


Fig 1: Pooled phenotypic range and mean of the five traits across 54 turmeric accessions.

4.2 Variation in days to maturity

Days to maturity displayed a pooled range of 197.75-243.50 days (Table 4). IT-1 matured earliest (197.75 days), followed by IT-28 (204.75 days), IT-3 (207.50 days), IT-39 (208.00 days), and IT-11 (208.50 days). The latest accessions were IT-43 (243.50 days),

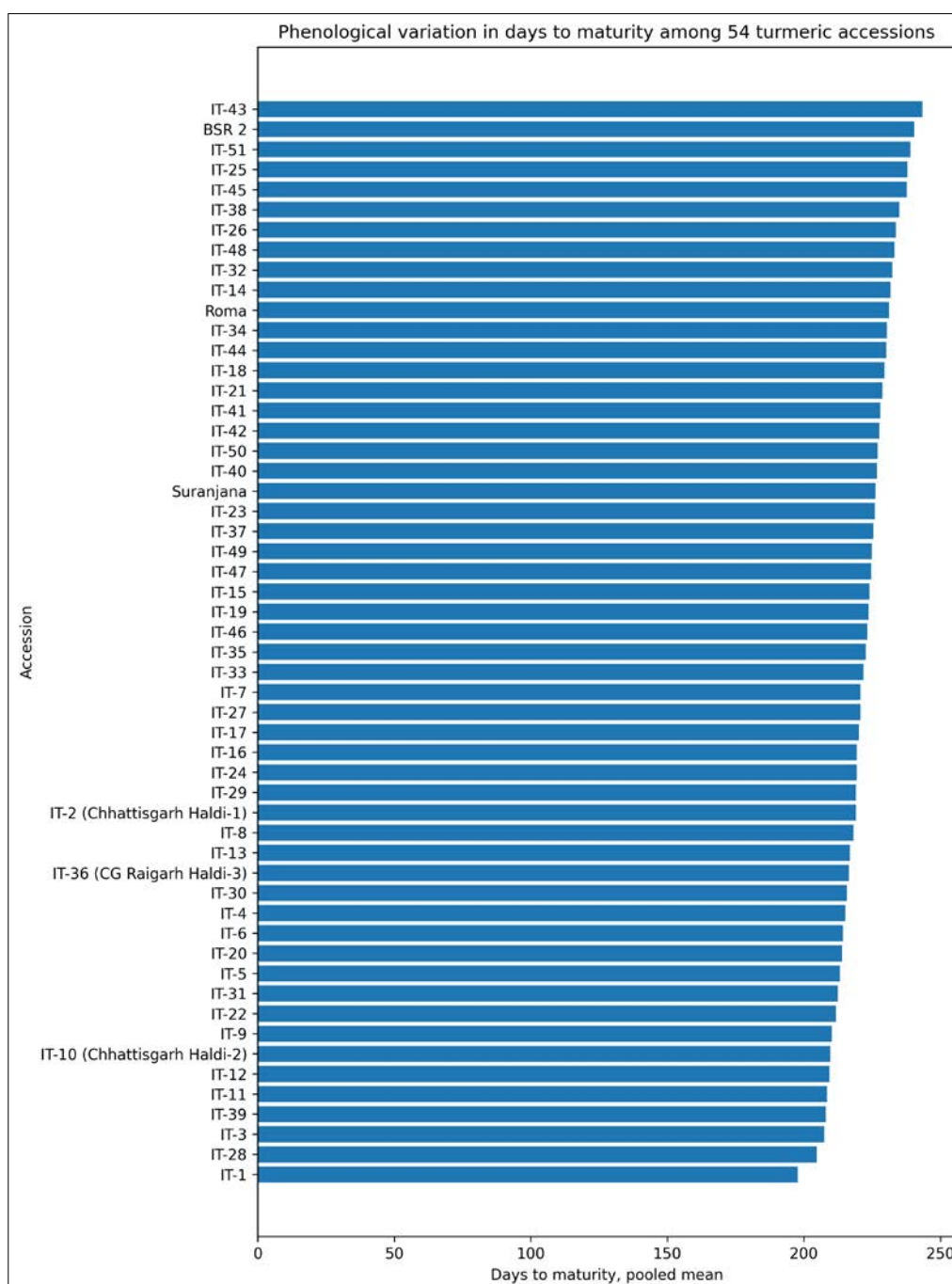
BSR-2 (240.50 days), IT-51 (239.00 days), IT-25 (238.00 days), and IT-45 (237.75 days). The difference between IT-43 and IT-1 was 45.75 days, indicating a substantial maturity contrast within the collection.

Table 4: Five earliest and five latest accessions for pooled days to maturity

Treatment	Treatment Details	Days to maturity
T1	IT-1	197.75
T28	IT-28	204.75
T3	IT-3	207.50
T39	IT-39	208.00
T11	IT-11	208.50
T45	IT-45	237.75
T25	IT-25	238.00
T51	IT-51	239.00
T54	BSR 2	240.50
T43	IT-43	243.50

The source document reports pooled SEM of 2.754 days, pooled CD (5%) of 7.81 days, and pooled CV of 1.75%. The 45.75-day difference between the extreme accessions is therefore much larger than the reported pooled CD, indicating a pronounced

separation under the statistical framework supplied with the dataset. The very low pooled CV relative to the trait mean also indicates comparatively consistent experimental precision for maturity

**Fig 2:** Pooled days to maturity for all 54 turmeric accessions, ordered from earliest to latest.

4.3 Variation in plant height

Plant height exhibited the strongest absolute structural contrast in the dataset, ranging from 74.71 cm in IT-43 to 134.79 cm in IT-1 (Table 5). The next highest accessions were IT-28 (133.96 cm), IT-3 (132.29 cm), IT-39 (130.92 cm), and IT-11 (128.47 cm). At

the lower end, BSR-2 (77.09 cm), IT-51 (77.59 cm), IT-25 (78.50 cm), and IT-45 (79.09 cm) clustered with IT-43. The pooled difference between IT-1 and IT-43 was 60.08 cm, equivalent to 80.4% of the IT-43 value.

Table 5: Ten accessions with the highest pooled plant height.

Treatment	Treatment Details	Plant height (cm)
T1	IT-1	134.79
T28	IT-28	133.96
T3	IT-3	132.29
T39	IT-39	130.92
T11	IT-11	128.47
T12	IT-12	126.93
T10	IT-10 (Chhattisgarh Haldi-2)	125.68
T9	IT-9	124.34
T22	IT-22	122.58
T31	IT-31	121.46

The supplied pooled SEM was 2.563 cm and the pooled CD at 5% was 7.27 cm. The extreme difference therefore exceeded the reported CD by more than eightfold. Such a large contrast is consistent with substantial phenotypic differentiation in plant stature within the evaluated germplasm.

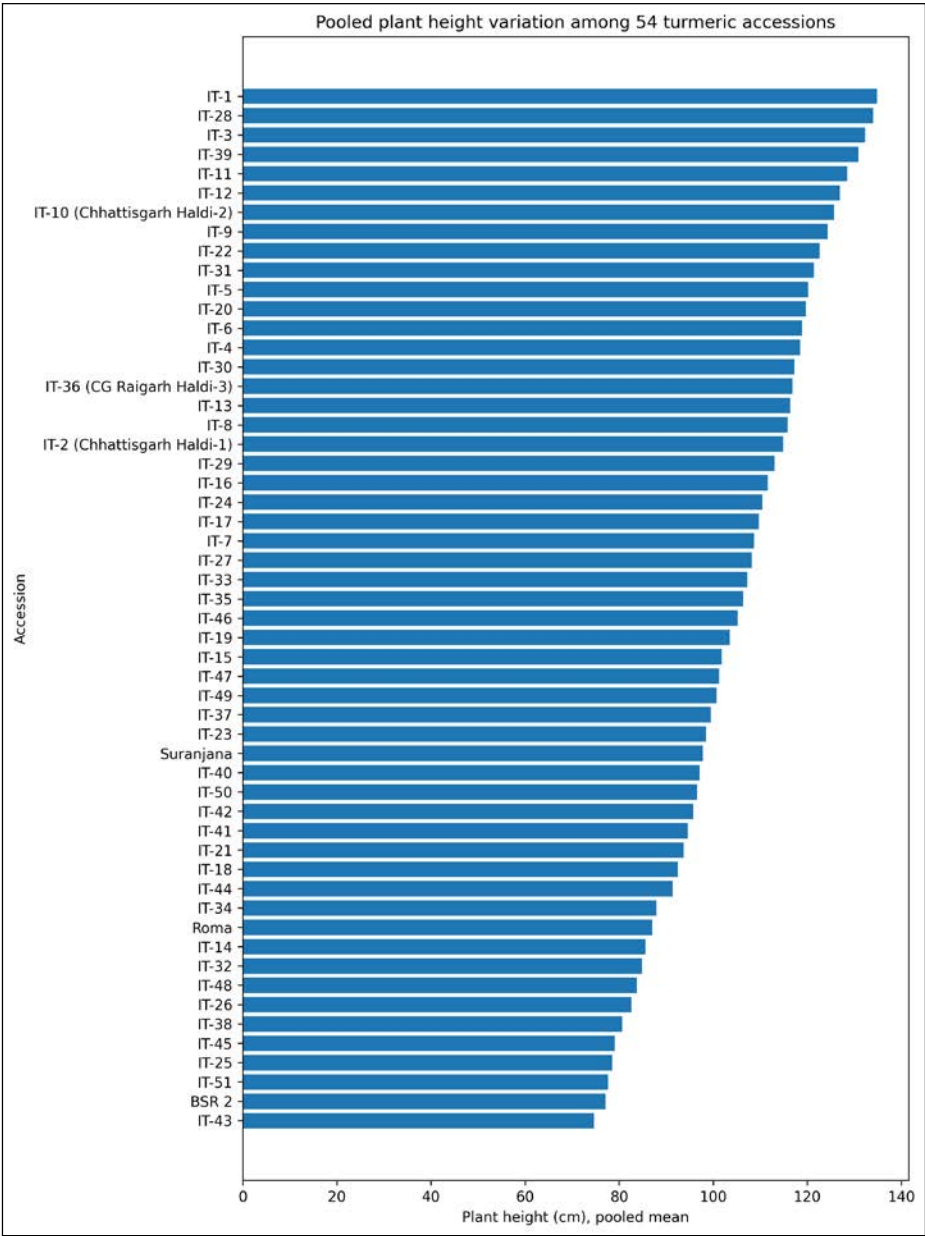


Fig 3: Pooled plant height of all 54 turmeric accessions.

4.4 Variation in number of shoots

Number of shoots varied from 2.04 in IT-43 to 6.16 in IT-1 (Table 6). The top group comprised IT-1, IT-28 (5.94), IT-3 (5.87), IT-39 (5.69), and IT-11 (5.64). The lowest group consisted of IT-43,

BSR-2 (2.10), IT-51 (2.13), IT-25 (2.36), and IT-45 (2.55). The maximum-to-minimum difference was 4.12 shoots, or approximately 202% of the minimum value.

Table 6: Ten accessions with the highest pooled number of shoots.

Treatment	Treatment Details	Number of shoots
T1	IT-1	6.16
T28	IT-28	5.94
T3	IT-3	5.87
T39	IT-39	5.69
T11	IT-11	5.64
T12	IT-12	5.50
T10	IT-10 (Chhattisgarh Haldi-2)	5.37
T9	IT-9	5.21
T22	IT-22	5.12
T31	IT-31	5.10

The pooled SEM was 0.128 and pooled CD (5%) was 0.36 shoots, while the pooled CV was 4.54%. The difference between IT-1 and IT-43 was therefore far larger than the supplied CD. The close correspondence between shoot number and the ranking of plant

height suggests that shoot proliferation and overall vegetative stature were expressed as a coordinated phenotype in this collection.

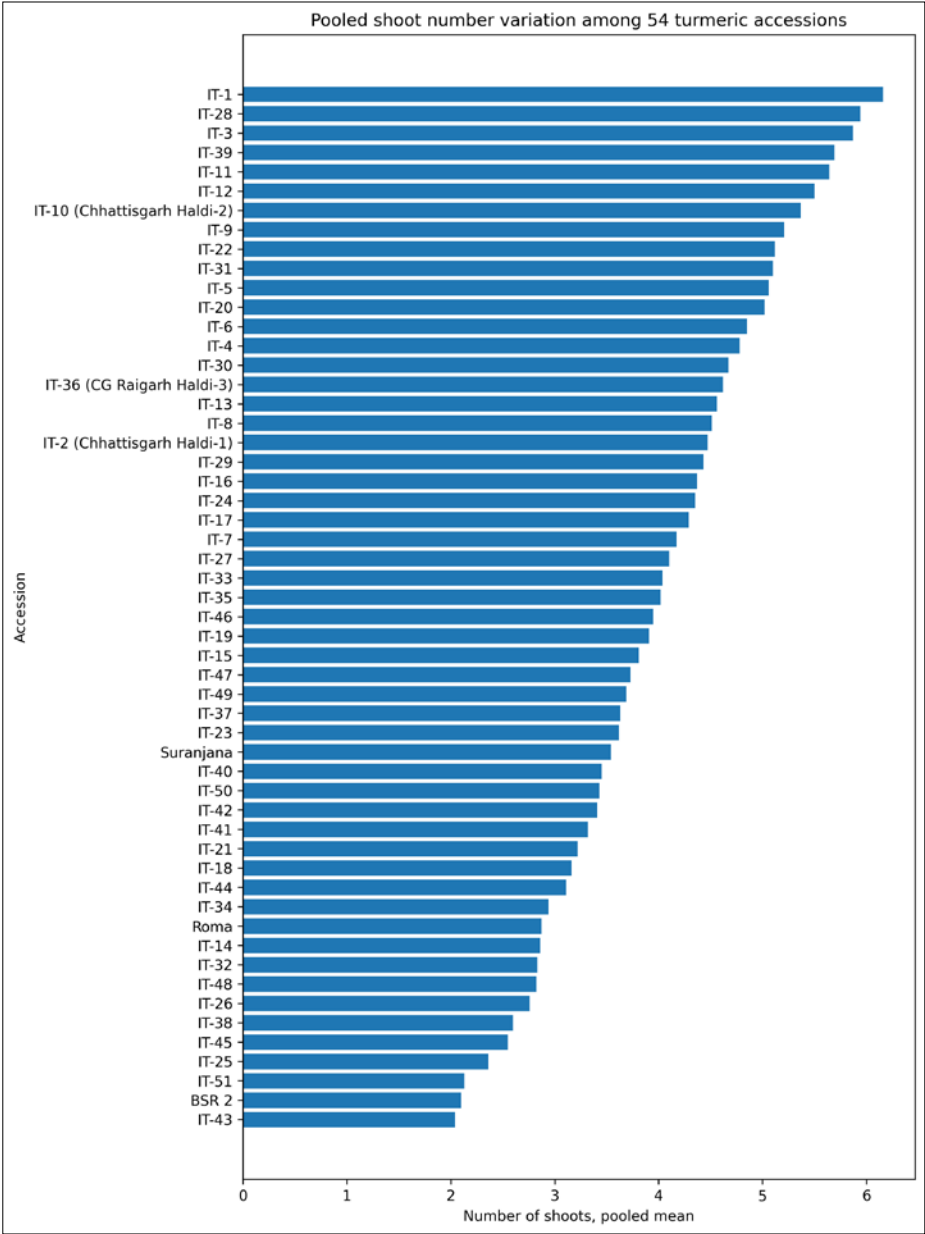


Fig 4: Pooled number of shoots for all 54 turmeric accessions.

4.5 Variation in leaves on main shoots

Leaves on main shoots ranged from 4.01 in IT-43 to 9.08 in IT-1 (Table 7). The highest values were recorded for IT-1, IT-28 (8.92), IT-3 (8.86), IT-39 (8.78), and IT-11 (8.61). The lowest

values were observed in IT-43, BSR-2 (4.37), IT-51 (4.40), IT-25 (4.56), and IT-45 (4.66). The 5.07-leaf contrast between the extremes represents a 126.4% difference relative to the lowest accession.

Table 7: Ten accessions with the highest pooled number of leaves on main shoots

Treatment	Treatment Details	Leaves on main shoots
T1	IT-1	9.08
T28	IT-28	8.92
T3	IT-3	8.86
T39	IT-39	8.78
T11	IT-11	8.61
T12	IT-12	8.54
T10	IT-10 (Chhattisgarh Haldi-2)	8.33
T9	IT-9	8.15
T22	IT-22	8.00
T31	IT-31	7.93

The source tables report pooled SEM of 0.215, pooled CD (5%) of 0.61 leaves, and pooled CV of 4.64%. The extreme difference was more than eight times the pooled CD. The parallel ranking of

leaf number with plant height and shoot number indicates that the collection contains distinct high-leaf and low-leaf plant architectures rather than isolated differences in a single character.

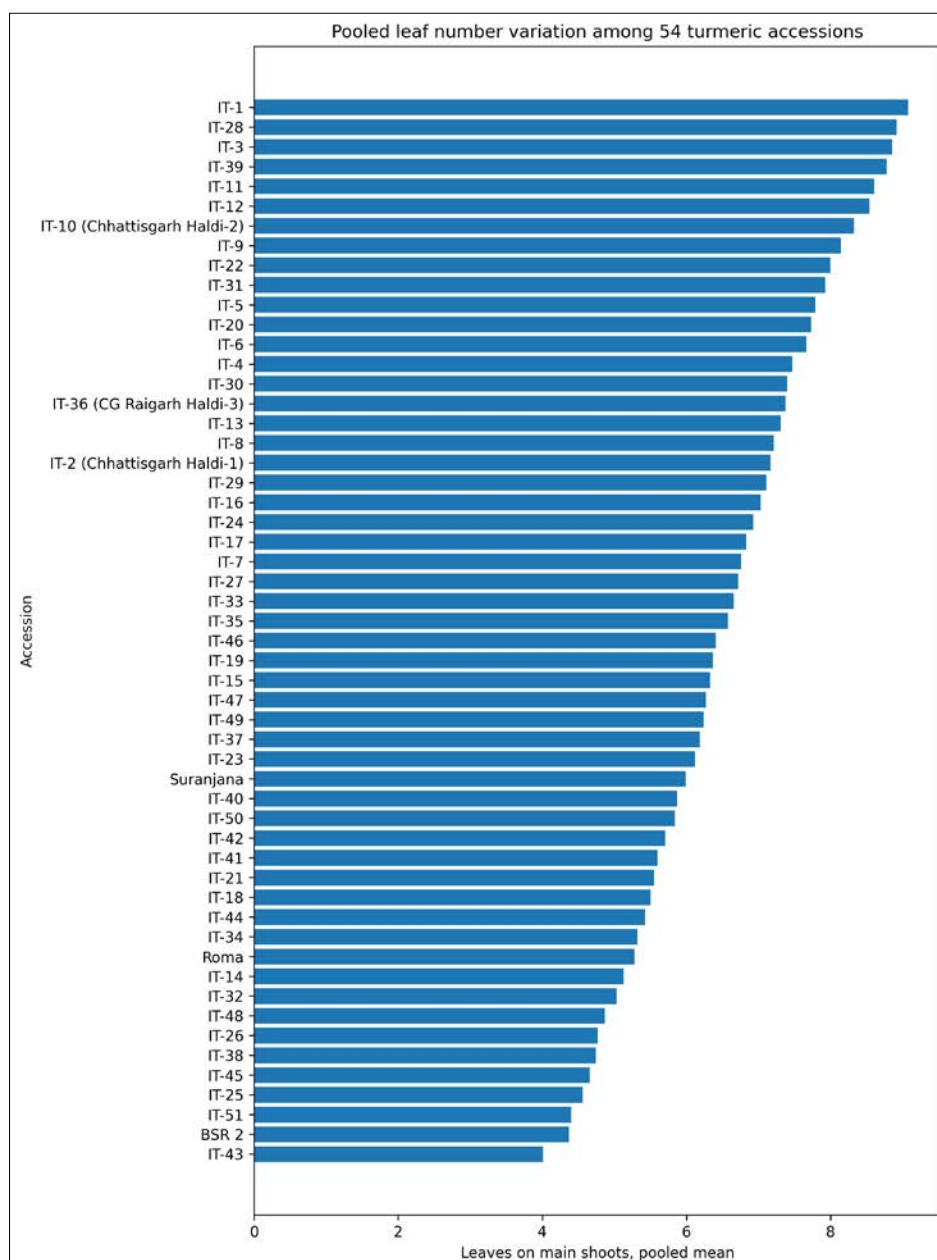


Fig 5: Pooled number of leaves on main shoots for all 54 turmeric accessions.

4.6 Variation in petiole length

Petiole length displayed the widest proportional variation among the measured structural traits, ranging from 11.39 cm in IT-43 to 35.18 cm in IT-1 (Table 8). The high group included IT-1, IT-28 (34.84 cm), IT-3 (34.63 cm), IT-39 (34.39 cm), and IT-11 (33.90 cm).

The low group included IT-43, BSR-2 (11.96 cm), IT-51 (12.10 cm), IT-25 (12.47 cm), and IT-45 (12.71 cm). The absolute difference between IT-1 and IT-43 was 23.79 cm, equivalent to 208.9% of the IT-43 value.

Table 8: Ten accessions with the highest pooled petiole length

Treatment	Treatment Details	Petiole length (cm)
T1	IT-1	35.18
T28	IT-28	34.84
T3	IT-3	34.63
T39	IT-39	34.39
T11	IT-11	33.90
T12	IT-12	33.52
T10	IT-10 (Chhattisgarh Haldi-2)	32.75
T9	IT-9	32.48
T22	IT-22	31.80
T31	IT-31	31.41

The pooled SEM for petiole length was 1.153 cm, the pooled CD was 3.27 cm, and the pooled CV was 7.03%. Again, the extreme contrast greatly exceeded the supplied CD. Because petiole length contributes to the spatial arrangement of the leaf canopy, its close

association with plant height and leaf number strengthens the interpretation that the collection contains distinct architectural types.

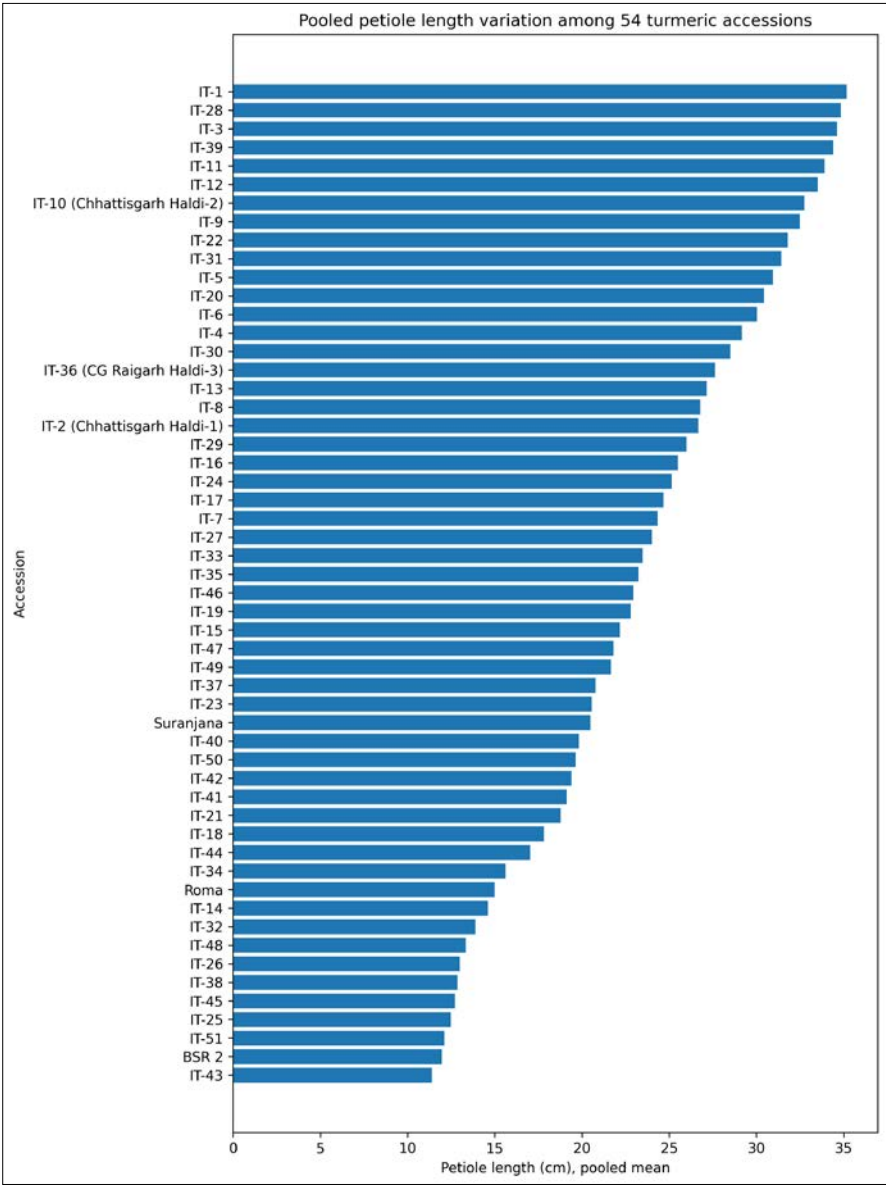


Fig 6: Pooled petiole length for all 54 turmeric accessions.

4.7 Seasonal comparison and consistency

Across all 54 accession means, the seasonal averages were remarkably stable (Table 9). Mean days to maturity changed by only 0.03 days between seasons, plant height increased by 0.99

cm, shoot number increased by 0.09, leaves on main shoots increased by 0.02, and petiole length increased by 0.33 cm. These small shifts indicate that the collection-level central tendency was broadly maintained across the two evaluation seasons.

Table 9: Across-accession seasonal means and year-to-year correlation of accession means

Trait	2021-22 mean	2022-23 mean	Change	Year-to-year r
Days to maturity	222.41	222.44	0.03	0.91
Plant height (cm)	104.40	105.39	0.99	0.99
Number of shoots	3.95	4.04	0.09	0.97
Leaves on main shoots	6.54	6.56	0.02	0.97
Petiole length (cm)	23.03	23.36	0.33	0.99

The strongest cross-season correspondence occurred for petiole length ($r = 0.991$) and plant height ($r = 0.988$), followed by leaves ($r = 0.967$) and shoot number ($r = 0.965$). Days to maturity also showed a strong association ($r = 0.907$). These coefficients

indicate that accession ranking was generally stable across years, although they are correlations of accession means and should not be interpreted as formal estimates of broad-sense heritability or genotype $\times$ environment stability.

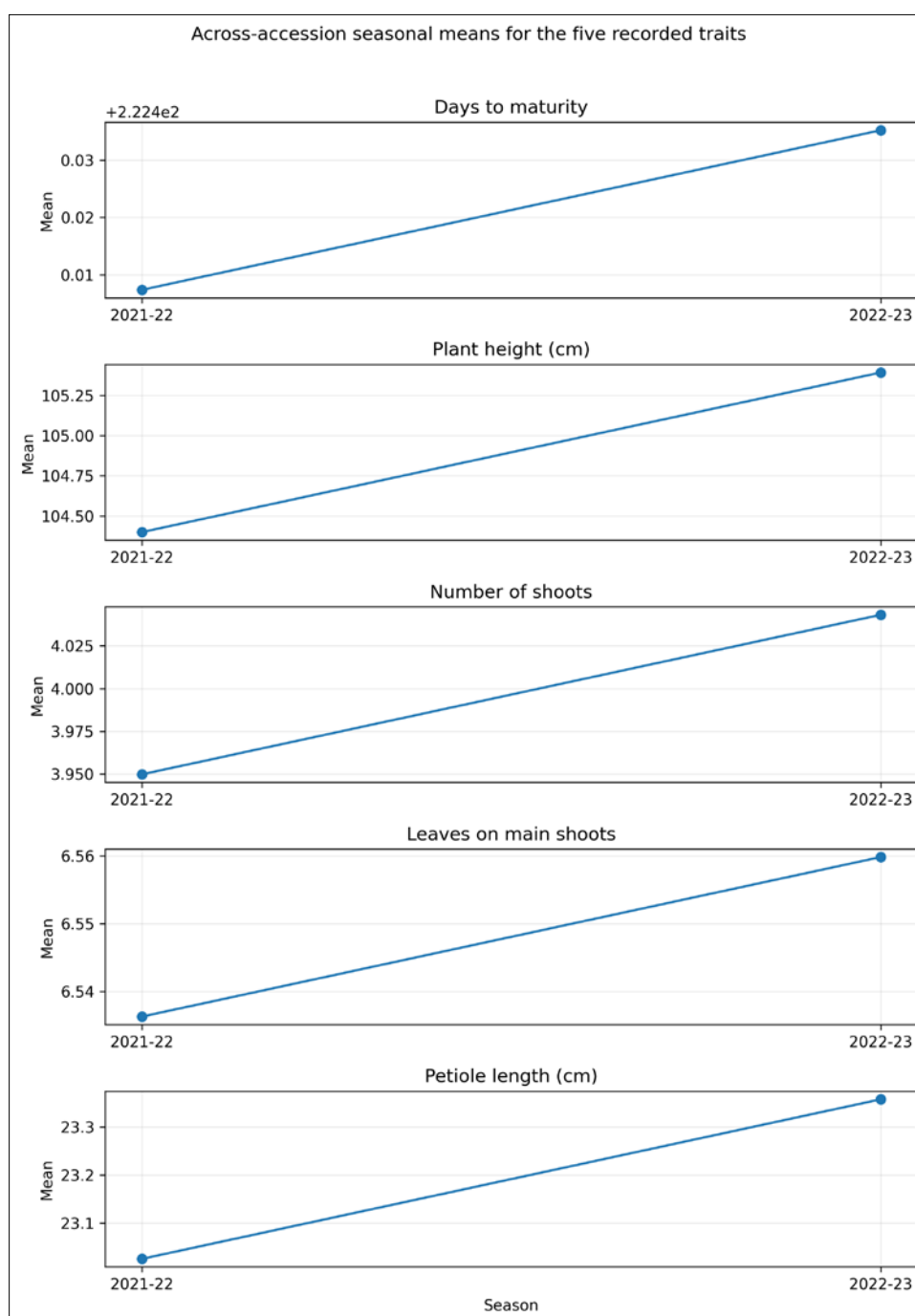


Fig 7: Across-accession means of the five recorded traits in 2021-22 and 2022-23.

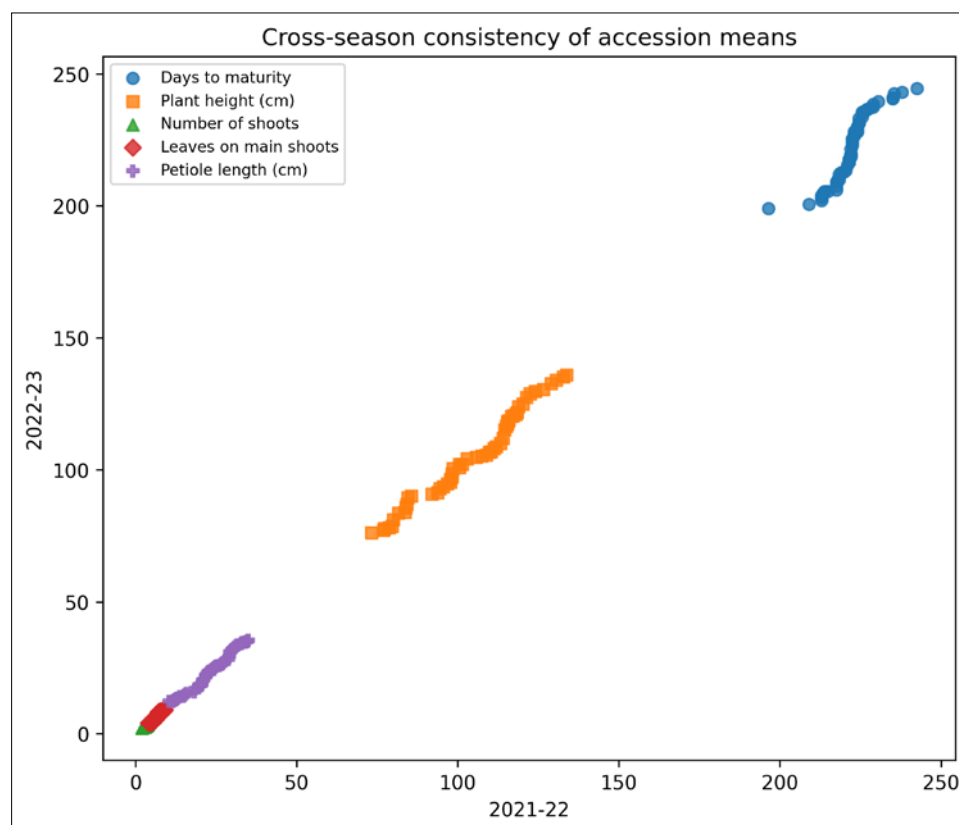


Fig 8: Cross-season consistency of accession means for the five traits.

4.9 Performance of named checks and Chhattisgarh materials

Table 11: Pooled performance of named Chhattisgarh materials and checks

Material	Days to maturity	Plant height (cm)	Number of shoots	Leaves on main shoots	Petiole length (cm)
IT-2 (Chhattisgarh Haldi-1)	219.00	114.87	4.47	7.17	26.67
IT-10 (Chhattisgarh Haldi-2)	209.75	125.68	5.37	8.33	32.75
IT-36 (CG Raigarh Haldi-3)	216.50	116.89	4.62	7.38	27.62
Roma	231.25	86.98	2.87	5.28	14.99
Suranjana	226.25	97.78	3.54	5.99	20.48
BSR 2	240.50	77.09	2.10	4.37	11.96

Among the three named Chhattisgarh accessions, IT-2 (Chhattisgarh Haldi-1) had 114.87 cm plant height, 4.47 shoots, 7.17 leaves on main shoots, and 26.67 cm petiole length, with pooled maturity of 219.00 days. IT-10 (Chhattisgarh Haldi-2) was somewhat more vigorous, with 125.68 cm height, 5.37 shoots, 8.33 leaves, and 32.75 cm petiole length, and matured in 209.75 days. IT-36 (CG Raigarh Haldi-3) showed intermediate values of 116.89 cm height, 4.62 shoots, 7.38 leaves, and 27.62 cm petiole length, with 216.50 days to maturity.

Among the three named checks, Roma showed 86.98 cm height and 14.99 cm petiole length, Suranjana showed 97.78 cm and 20.48 cm, and BSR-2 showed 77.09 cm and 11.96 cm, respectively. Thus, the local Chhattisgarh materials, particularly IT-10, expressed stronger vegetative growth than the named checks in this dataset. Such comparisons are useful for identifying regional materials that merit further testing, but superiority for growth alone should not be equated with superiority for yield, curcumin content, disease resistance, or market quality.

Table 12: Statistical precision values supplied with the original dataset

Trait	SEm 2021-22	SEm 2022-23	SEm pooled	CD 2021-22	CD 2022-23	CD pooled	CV 2021-22 (%)	CV 2022-23 (%)	CV pooled (%)
Days to maturity	3.70	5.55	2.75	10.50	15.74	7.81	2.35	3.53	1.75
Plant height (cm)	3.99	3.88	2.56	11.31	10.99	7.27	5.40	5.20	3.46
Number of shoots	0.15	0.21	0.13	0.42	0.60	0.36	5.31	7.44	4.54
Leaves on main shoots	0.28	0.30	0.21	0.79	0.86	0.61	6.03	6.53	4.64
Petiole length (cm)	1.49	1.60	1.15	4.23	4.55	3.27	9.15	9.71	7.03

5. Discussion

5.1 Magnitude and biological coherence of growth variation

The principal outcome of the present evaluation is the magnitude and coherence of phenotypic differentiation among the 54 indigenous accessions. Variation was not confined to one

character: the same accessions repeatedly occupied the upper or lower ranks for plant height, shoot number, leaf number, and petiole length. IT-1, IT-28, IT-3, IT-39, and IT-11 formed the recurring high-growth group, whereas IT-43, BSR-2, IT-51, IT-25, and IT-45 formed the recurring low-growth group. This

coordinated ranking is important because it suggests that the observed diversity reflects contrasting plant architectures rather than isolated fluctuations in individual traits. The magnitude of variation agrees with the broader turmeric literature. Roy *et al.* (2011) ^[10] reported substantial agro-morphological diversity among turmeric accessions and identified plant height and leaf number among traits associated with rhizome yield. Mishra *et al.* (2015) ^[8] also found considerable variability among 65 germplasms and reported very high broad-sense heritability for plant height. Gupta *et al.* (2016) ^[6] identified substantial variability and interrelationships among 13 agro-morphological traits, reinforcing the value of vegetative characters as components of turmeric phenotypic characterization. An especially close methodological parallel is provided by Anindita *et al.* (2020) ^[1], whose turmeric dataset included plant height, number of shoots, number of leaves on the main shoot, and petiole length as distinguishing phenotypic traits. The present Raigarh dataset reproduces this same core architectural set and demonstrates that these traits can jointly discriminate accessions in a geographically different germplasm context. Although the two collections cannot be directly compared numerically because their environments and genetic materials differ, the recurrence of the same informative trait classes supports their continued use in germplasm characterization.

5.2 Early maturity versus vegetative vigor

One of the most striking patterns was the inverse relationship between maturity duration and vegetative expression. The pooled correlation between days to maturity and plant height was -0.989, and correlations with shoots, leaves, and petiole length were similarly negative (-0.994, -0.992, and -0.984, respectively). At the phenotypic level, this indicates that accessions requiring more days to maturity tended, within this particular collection, to have lower values for the measured structural growth traits. The extreme contrast between IT-1 and IT-43 illustrates this pattern: IT-1 matured 45.75 days earlier while simultaneously exceeding IT-43 by 60.08 cm in height, 4.12 shoots, 5.07 leaves, and 23.79 cm in petiole length. Such a relationship should not automatically be interpreted as a universal physiological rule for turmeric. Days to maturity integrates developmental progression and environmental response, while plant height, shoot number, leaf number, and petiole length describe structural expression. The strong inverse association may therefore reflect the particular genetic composition of this collection, correlated developmental strategies, or shared responses to the environmental conditions of the evaluation site. Patel *et al.* (2023) ^[9] also emphasized variation in days to maturity and other agronomic traits among Indian turmeric genotypes, illustrating that phenology can be a useful discriminating character in germplasm evaluation. From a breeding perspective, the pattern creates an important selection question: whether early maturity and vigorous vegetative growth can be retained simultaneously in a genotype. IT-1 is notable precisely because it combines both features in the supplied data. However, because rhizome yield and quality are absent from the current dataset, it would be scientifically inappropriate to conclude that IT-1 is a superior production genotype. Instead, it should be regarded as a high-priority candidate for subsequent yield and quality testing.

5.3 Plant architecture and potential functional interpretation

Plant height, shoot number, leaf number, and petiole length were all positively correlated at values approaching unity. The plant architecture implied by these data is internally consistent: accessions with more shoots also tended to have taller plants,

more leaves on the main shoot, and longer petioles. Such coordinated expression is biologically plausible because shoot initiation, leaf production, petiole elongation, and overall canopy extension are interconnected components of vegetative development. Nevertheless, the present dataset does not contain leaf area, biomass, photosynthetic rate, light interception, or rhizome accumulation measurements; therefore, mechanistic explanations should remain hypotheses rather than direct conclusions. The close association between vegetative traits and agronomic performance has been noted in turmeric research. Roy *et al.* (2011) ^[10] reported positive associations of plant height and leaf number with rhizome yield in north-eastern Indian accessions. Das *et al.* (2026) ^[2] similarly documented significant variability in plant height and other growth attributes and demonstrated that growth characters can contribute to multivariate differentiation among turmeric genotypes. These studies support the use of plant architecture as a useful intermediate phenotype, while also emphasizing that yield relationships must be validated independently. The present results also suggest that petiole length deserves greater attention in regional turmeric characterization. It had a pooled descriptive CV of 7.03%, somewhat higher than plant height (3.46%) and leaves on main shoots (4.64%) but still within a moderate experimental range, and it exhibited very high cross-season consistency ($r = 0.991$). This combination of measurable variability and strong temporal consistency makes petiole length potentially useful as a complementary descriptor, particularly when combined with other architecture traits.

5.4 Consistency across seasons

The two-season comparison provides an important robustness check. Across the collection, seasonal means changed only slightly, while the accession-level correlations between years were high for every trait. Plant height and petiole length showed the strongest cross-season correspondence, suggesting that accession ranking for these structural traits was highly conserved between 2021-22 and 2022-23. Days to maturity showed the lowest, though still strong, correlation ($r = 0.907$), indicating somewhat greater sensitivity of accession ranking for phenological duration. This consistency is valuable for germplasm selection because a phenotype that persists across seasons is more useful as a screening character than one that is strongly season-dependent. However, the present analysis cannot partition the causes of stability. No environmental covariates, replication-level observations, or genotype $\times$ environment interaction statistics were provided. Therefore, the results demonstrate repeatability of accession means within the two supplied seasons, not formal stability across environments. The low pooled CV values reported in the original tables further support the precision of the trial. Pooled CV ranged from 1.75% for days to maturity to 7.03% for petiole length. These values indicate that experimental variation relative to the trait means was comparatively limited. The combination of low CV, reported CD values, and strong cross-season correlations strengthens confidence that the major contrasts are not simply the result of random experimental noise.

5.5 Implications for Indian turmeric germplasm management

India possesses extensive turmeric diversity, and molecular studies have demonstrated that indigenous collections retain substantial genetic variation. Verma *et al.* (2015) ^[12] detected high polymorphism and broad genetic distances among Indian turmeric genotypes, while Dudekula *et al.* (2022) ^[4] demonstrated that Indian germplasm can be differentiated using rhizome yield

traits and curcuminoid profiles. Against this background, the present regional collection should be viewed as a phenotypic layer of a larger conservation and pre-breeding strategy.

The Chhattisgarh materials included in the experiment are particularly relevant for regional breeding. IT-10 (Chhattisgarh Haldi-2) expressed a comparatively strong vegetative phenotype and relatively early pooled maturity, whereas IT-36 showed an intermediate architecture and IT-2 was more moderate in growth. These differences provide a rational basis for prioritizing materials for follow-up trials under local conditions. Yet a breeding programme should avoid selecting exclusively for vegetative vigor because rhizome yield, dry recovery, curcumin content, disease resistance, and market-preferred quality can respond differently. Recent molecular work also supports integrating phenotypic and molecular evidence. Patel *et al.* (2023)^[9] combined morphological characterization with SSR-based molecular diversity, while Verma *et al.* (2015)^[12] used DAMD and ISSR markers to reveal genetic relationships among indigenous Indian turmeric. A logical next step for the Raigarh material would therefore be to combine the present growth descriptors with rhizome yield and quality measurements and, where resources permit, molecular marker data. Such integration would help distinguish accessions that are merely vigorous from those that combine desirable architecture with commercially valuable rhizome traits.

5.6 Methodological significance and limitations

The present study deliberately follows a data-conservative analytical strategy. Only values explicitly provided in the source document were used. Consequently, the manuscript does not

invent F-statistics, genotype $\times$ environment effects, heritability estimates, genetic advance, or replication-level distributions. This is important because the source file supplies treatment means and summary error statistics, but not the complete raw experimental matrix required to reconstruct every conventional quantitative-genetic parameter.

The strongest limitation is therefore the absence of yield and quality variables in the supplied Paper 2 growth dataset. Growth superiority cannot be assumed to translate into rhizome yield superiority. A second limitation is that the Pearson correlation analysis uses pooled accession means, so the very high coefficients should be interpreted as descriptors of coordinated accession phenotype rather than as genetic correlations. A third limitation is that only two seasons at one research location are represented; broader adaptation requires multi-location and multi-year testing. Despite these limitations, the study has a clear practical value: it identifies a small set of contrasting accessions that can be targeted for the next stage of evaluation. IT-1, IT-28, IT-3, IT-39, and IT-11 repeatedly ranked highly for structural growth, while IT-43, BSR-2, IT-51, IT-25, and IT-45 represented the opposite end. Such contrasting material is valuable for parent selection, descriptor development, and studies of the biological basis of architecture and maturity.

Supplementary Tables

The following tables reproduce the complete numerical dataset. Values are transcribed from the original document; the pooled column is the source-reported pooled mean. These tables are included to preserve transparency and allow verification of all accession-level analyses reported in the manuscript.

Supplementary Table S1: Complete accession-wise data for Days to maturity

Treatment	Accession	2021-22	2022-23	Pooled
T1	IT-1	196.50	199.00	197.75
T2	IT-2 (Chhattisgarh Haldi-1)	221.50	216.50	219.00
T3	IT-3	213.00	202.00	207.50
T4	IT-4	218.50	212.00	215.25
T5	IT-5	217.50	209.00	213.25
T6	IT-6	218.50	210.00	214.25
T7	IT-7	222.00	219.50	220.75
T8	IT-8	221.00	215.50	218.25
T9	IT-9	215.00	205.50	210.25
T10	IT-10 (Chhattisgarh Haldi-2)	214.00	205.50	209.75
T11	IT-11	213.00	204.00	208.50
T12	IT-12	213.50	205.00	209.25
T13	IT-13	220.50	213.50	217.00
T14	IT-14	227.00	236.50	231.75
T15	IT-15	222.50	225.50	224.00
T16	IT-16	221.50	217.50	219.50
T17	IT-17	222.00	218.50	220.25
T18	IT-18	225.50	233.50	229.50
T19	IT-19	222.50	225.00	223.75
T20	IT-20	218.00	210.00	214.00
T21	IT-21	224.50	233.00	228.75
T22	IT-22	217.50	206.00	211.75
T23	IT-23	224.00	228.00	226.00
T24	IT-24	221.50	217.50	219.50
T25	IT-25	235.00	241.00	238.00
T26	IT-26	229.00	238.50	233.75
T27	IT-27	222.00	219.50	220.75
T28	IT-28	209.00	200.50	204.75
T29	IT-29	221.50	216.50	219.00
T30	IT-30	219.00	212.50	215.75
T31	IT-31	217.50	207.50	212.50
T32	IT-32	228.00	237.00	232.50
T33	IT-33	222.00	221.50	221.75

T34	IT-34	225.50	235.50	230.50
T35	IT-35	222.50	223.00	222.75
T36	IT-36 (CG Raigarh Haldi-3)	220.00	213.00	216.50
T37	IT-37	223.00	228.00	225.50
T38	IT-38	230.50	239.50	235.00
T39	IT-39	213.00	203.00	208.00
T40	IT-40	224.00	229.50	226.75
T41	IT-41	224.50	231.50	228.00
T42	IT-42	224.50	231.00	227.75
T43	IT-43	242.50	244.50	243.50
T44	IT-44	225.50	235.00	230.25
T45	IT-45	235.00	240.50	237.75
T46	IT-46	222.50	224.00	223.25
T47	IT-47	223.00	226.50	224.75
T48	IT-48	229.00	237.50	233.25
T49	IT-49	223.00	227.00	225.00
T50	IT-50	224.00	230.00	227.00
T51	IT-51	235.50	242.50	239.00
T52	Roma	226.50	236.00	231.25
T53	Suranjana	224.00	228.50	226.25
T54	BSR 2	238.00	243.00	240.50

Supplementary Table S2: Complete accession-wise data for Plant height (cm).

Treatment	Accession	2021-22	2022-23	Pooled
T1	IT-1	133.75	135.84	134.79
T2	IT-2 (Chhattisgarh Haldi-1)	114.57	115.17	114.87
T3	IT-3	130.57	134.01	132.29
T4	IT-4	116.74	120.29	118.52
T5	IT-5	118.43	121.89	120.16
T6	IT-6	117.25	120.56	118.90
T7	IT-7	110.43	106.90	108.67
T8	IT-8	115.20	116.53	115.86
T9	IT-9	121.31	127.38	124.34
T10	IT-10 (Chhattisgarh Haldi-2)	122.44	128.92	125.68
T11	IT-11	126.52	130.42	128.47
T12	IT-12	124.14	129.73	126.93
T13	IT-13	115.36	117.34	116.35
T14	IT-14	84.24	86.95	85.59
T15	IT-15	101.44	102.18	101.81
T16	IT-16	113.25	110.00	111.62
T17	IT-17	111.21	108.17	109.69
T18	IT-18	93.71	91.27	92.49
T19	IT-19	102.79	104.26	103.52
T20	IT-20	118.19	121.10	119.64
T21	IT-21	94.49	92.88	93.68
T22	IT-22	120.14	125.02	122.58
T23	IT-23	98.25	98.62	98.43
T24	IT-24	112.02	108.80	110.41
T25	IT-25	78.80	78.20	78.50
T26	IT-26	81.61	83.56	82.59
T27	IT-27	109.73	106.73	108.23
T28	IT-28	132.77	135.15	133.96
T29	IT-29	114.11	111.96	113.04
T30	IT-30	115.91	118.63	117.27
T31	IT-31	118.95	123.98	121.46
T32	IT-32	83.97	85.77	84.87
T33	IT-33	108.92	105.60	107.26
T34	IT-34	85.62	90.14	87.88
T35	IT-35	107.51	105.26	106.39
T36	IT-36 (CG Raigarh Haldi-3)	115.46	118.31	116.89
T37	IT-37	98.55	100.44	99.49
T38	IT-38	80.08	81.12	80.60
T39	IT-39	129.07	132.78	130.92
T40	IT-40	97.75	96.54	97.15
T41	IT-41	95.53	93.62	94.58
T42	IT-42	96.75	94.76	95.76
T43	IT-43	73.21	76.22	74.71

T44	IT-44	92.01	90.81	91.41
T45	IT-45	79.57	78.61	79.09
T46	IT-46	105.72	104.69	105.20
T47	IT-47	100.54	102.02	101.28
T48	IT-48	83.61	83.99	83.80
T49	IT-49	100.54	100.89	100.71
T50	IT-50	97.75	95.38	96.56
T51	IT-51	77.34	77.85	77.59
T52	Roma	84.50	89.47	86.98
T53	Suranjana	98.25	97.31	97.78
T54	BSR 2	77.03	77.14	77.09

Supplementary Table S3: Complete accession-wise data for Number of shoots

Treatment	Accession	2021-22	2022-23	Pooled
T1	IT-1	6.10	6.22	6.16
T2	IT-2 (Chhattisgarh Haldi-1)	4.37	4.57	4.47
T3	IT-3	5.64	6.10	5.87
T4	IT-4	4.56	5.01	4.78
T5	IT-5	4.67	5.46	5.06
T6	IT-6	4.59	5.11	4.85
T7	IT-7	4.16	4.19	4.17
T8	IT-8	4.39	4.64	4.51
T9	IT-9	4.81	5.61	5.21
T10	IT-10 (Chhattisgarh Haldi-2)	5.06	5.68	5.37
T11	IT-11	5.34	5.94	5.64
T12	IT-12	5.22	5.79	5.50
T13	IT-13	4.41	4.72	4.56
T14	IT-14	3.00	2.71	2.86
T15	IT-15	3.87	3.75	3.81
T16	IT-16	4.32	4.43	4.37
T17	IT-17	4.27	4.32	4.29
T18	IT-18	3.37	2.94	3.16
T19	IT-19	3.97	3.85	3.91
T20	IT-20	4.62	5.41	5.02
T21	IT-21	3.40	3.04	3.22
T22	IT-22	4.68	5.56	5.12
T23	IT-23	3.70	3.54	3.62
T24	IT-24	4.30	4.40	4.35
T25	IT-25	2.30	2.43	2.36
T26	IT-26	2.92	2.60	2.76
T27	IT-27	4.07	4.13	4.10
T28	IT-28	5.76	6.13	5.94
T29	IT-29	4.34	4.51	4.43
T30	IT-30	4.44	4.91	4.67
T31	IT-31	4.67	5.54	5.10
T32	IT-32	2.99	2.67	2.83
T33	IT-33	4.04	4.04	4.04
T34	IT-34	3.04	2.83	2.94
T35	IT-35	4.03	4.02	4.02
T36	IT-36 (CG Raigarh Haldi-3)	4.42	4.82	4.62
T37	IT-37	3.71	3.55	3.63
T38	IT-38	2.68	2.52	2.60
T39	IT-39	5.36	6.03	5.69
T40	IT-40	3.67	3.23	3.45
T41	IT-41	3.57	3.08	3.32
T42	IT-42	3.65	3.18	3.41
T43	IT-43	1.96	2.12	2.04
T44	IT-44	3.33	2.88	3.11
T45	IT-45	2.63	2.46	2.55
T46	IT-46	3.98	3.92	3.95
T47	IT-47	3.76	3.70	3.73
T48	IT-48	2.99	2.66	2.82
T49	IT-49	3.76	3.62	3.69
T50	IT-50	3.67	3.20	3.43
T51	IT-51	2.01	2.25	2.13
T52	Roma	3.03	2.72	2.87
T53	Suranjana	3.70	3.39	3.54

T54	BSR 2	1.99	2.20	2.10
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Supplementary Table S4: Complete accession-wise data for Leaves on main shoots

Treatment	Accession	2021-22	2022-23	Pooled
T1	IT-1	9.07	9.10	9.08
T2	IT-2 (Chhattisgarh Haldi-1)	6.96	7.39	7.17
T3	IT-3	8.72	8.99	8.86
T4	IT-4	7.12	7.83	7.47
T5	IT-5	7.27	8.32	7.79
T6	IT-6	7.17	8.18	7.67
T7	IT-7	6.67	6.84	6.76
T8	IT-8	6.99	7.43	7.21
T9	IT-9	7.78	8.52	8.15
T10	IT-10 (Chhattisgarh Haldi-2)	8.06	8.61	8.33
T11	IT-11	8.44	8.79	8.61
T12	IT-12	8.38	8.71	8.54
T13	IT-13	7.00	7.62	7.31
T14	IT-14	5.40	4.85	5.13
T15	IT-15	6.35	6.32	6.33
T16	IT-16	6.85	7.22	7.03
T17	IT-17	6.69	6.97	6.83
T18	IT-18	5.78	5.22	5.50
T19	IT-19	6.37	6.37	6.37
T20	IT-20	7.22	8.25	7.73
T21	IT-21	5.83	5.27	5.55
T22	IT-22	7.53	8.47	8.00
T23	IT-23	6.29	5.96	6.12
T24	IT-24	6.76	7.11	6.93
T25	IT-25	4.79	4.33	4.56
T26	IT-26	5.04	4.50	4.77
T27	IT-27	6.64	6.81	6.72
T28	IT-28	8.82	9.02	8.92
T29	IT-29	6.89	7.33	7.11
T30	IT-30	7.06	7.75	7.40
T31	IT-31	7.48	8.37	7.93
T32	IT-32	5.39	4.68	5.03
T33	IT-33	6.61	6.71	6.66
T34	IT-34	5.59	5.05	5.32
T35	IT-35	6.56	6.59	6.58
T36	IT-36 (CG Raigarh Haldi-3)	7.04	7.73	7.38
T37	IT-37	6.32	6.07	6.19
T38	IT-38	4.99	4.50	4.74
T39	IT-39	8.66	8.89	8.78
T40	IT-40	6.14	5.60	5.87
T41	IT-41	5.92	5.28	5.60
T42	IT-42	6.03	5.40	5.71
T43	IT-43	3.98	4.04	4.01
T44	IT-44	5.75	5.11	5.43
T45	IT-45	4.92	4.41	4.66
T46	IT-46	6.42	6.39	6.41
T47	IT-47	6.34	6.21	6.27
T48	IT-48	5.23	4.52	4.87
T49	IT-49	6.34	6.15	6.24
T50	IT-50	6.14	5.53	5.84
T51	IT-51	4.68	4.12	4.40
T52	Roma	5.53	5.03	5.28
T53	Suranjana	6.29	5.70	5.99
T54	BSR 2	4.67	4.07	4.37

Supplementary Table S5: Complete accession-wise data for Petiole length (cm)

Treatment	Accession	2021-22	2022-23	Pooled
T1	IT-1	34.95	35.42	35.18
T2	IT-2 (Chhattisgarh Haldi-1)	26.75	26.59	26.67
T3	IT-3	34.35	34.90	34.63
T4	IT-4	29.00	29.31	29.16
T5	IT-5	29.90	31.99	30.95
T6	IT-6	29.20	30.87	30.04

T7	IT-7	24.20	24.48	24.34
T8	IT-8	26.90	26.68	26.79
T9	IT-9	31.40	33.57	32.48
T10	IT-10 (Chhattisgarh Haldi-2)	31.85	33.65	32.75
T11	IT-11	33.15	34.65	33.90
T12	IT-12	32.85	34.19	33.52
T13	IT-13	27.20	27.07	27.14
T14	IT-14	14.85	14.38	14.61
T15	IT-15	21.90	22.44	22.17
T16	IT-16	25.15	25.83	25.49
T17	IT-17	24.20	25.14	24.67
T18	IT-18	18.45	17.19	17.82
T19	IT-19	22.35	23.23	22.79
T20	IT-20	29.65	31.22	30.43
T21	IT-21	19.55	17.99	18.77
T22	IT-22	30.70	32.90	31.80
T23	IT-23	20.80	20.31	20.55
T24	IT-24	24.80	25.50	25.15
T25	IT-25	12.10	12.84	12.47
T26	IT-26	12.65	13.30	12.98
T27	IT-27	23.70	24.34	24.02
T28	IT-28	34.60	35.09	34.84
T29	IT-29	26.00	25.98	25.99
T30	IT-30	28.70	28.32	28.51
T31	IT-31	30.50	32.31	31.41
T32	IT-32	13.70	14.09	13.90
T33	IT-33	23.20	23.78	23.49
T34	IT-34	15.80	15.43	15.62
T35	IT-35	22.70	23.76	23.23
T36	IT-36 (CG Raigarh Haldi-3)	27.70	27.55	27.62
T37	IT-37	21.15	20.43	20.79
T38	IT-38	12.55	13.19	12.87
T39	IT-39	34.00	34.79	34.39
T40	IT-40	20.45	19.19	19.82
T41	IT-41	20.00	18.24	19.12
T42	IT-42	20.35	18.46	19.40
T43	IT-43	10.45	12.34	11.39
T44	IT-44	18.15	15.92	17.03
T45	IT-45	12.30	13.11	12.71
T46	IT-46	22.50	23.40	22.95
T47	IT-47	21.70	21.93	21.82
T48	IT-48	13.05	13.63	13.34
T49	IT-49	21.70	21.62	21.66
T50	IT-50	20.45	18.84	19.65
T51	IT-51	11.65	12.54	12.10
T52	Roma	15.20	14.78	14.99
T53	Suranjana	20.80	20.17	20.48
T54	BSR 2	11.50	12.142	11.96

Supplementary ranking and interpretation tables

Supplementary Table S6: Accession ranks derived from the supplied pooled means

Treatment	Accession	Maturity rank (1=early)	Height rank	Shoot rank	Leaf rank	Petiole rank
T1	IT-1	1.00	1.00	1.00	1.00	1.00
T2	IT-2 (Chhattisgarh Haldi-1)	19.00	19.00	19.00	19.00	19.00
T3	IT-3	3.00	3.00	3.00	3.00	3.00
T4	IT-4	14.00	14.00	14.00	14.00	14.00
T5	IT-5	11.00	11.00	11.00	11.00	11.00
T6	IT-6	13.00	13.00	13.00	13.00	13.00
T7	IT-7	24.00	24.00	24.00	24.00	24.00
T8	IT-8	18.00	18.00	18.00	18.00	18.00
T9	IT-9	8.00	8.00	8.00	8.00	8.00
T10	IT-10 (Chhattisgarh Haldi-2)	7.00	7.00	7.00	7.00	7.00
T11	IT-11	5.00	5.00	5.00	5.00	5.00
T12	IT-12	6.00	6.00	6.00	6.00	6.00
T13	IT-13	17.00	17.00	17.00	17.00	17.00
T14	IT-14	45.00	45.00	45.00	45.00	45.00

T15	IT-15	30.00	30.00	30.00	30.00	30.00
T16	IT-16	21.00	21.00	21.00	21.00	21.00
T17	IT-17	23.00	23.00	23.00	23.00	23.00
T18	IT-18	41.00	41.00	41.00	41.00	41.00
T19	IT-19	29.00	29.00	29.00	29.00	29.00
T20	IT-20	12.00	12.00	12.00	12.00	12.00
T21	IT-21	40.00	40.00	40.00	40.00	40.00
T22	IT-22	9.00	9.00	9.00	9.00	9.00
T23	IT-23	34.00	34.00	34.00	34.00	34.00
T24	IT-24	21.00	22.00	22.00	22.00	22.00
T25	IT-25	51.00	51.00	51.00	51.00	51.00
T26	IT-26	48.00	48.00	48.00	48.00	48.00
T27	IT-27	24.00	25.00	25.00	25.00	25.00
T28	IT-28	2.00	2.00	2.00	2.00	2.00
T29	IT-29	19.00	20.00	20.00	20.00	20.00
T30	IT-30	15.00	15.00	15.00	15.00	15.00
T31	IT-31	10.00	10.00	10.00	10.00	10.00
T32	IT-32	46.00	46.00	46.00	46.00	46.00
T33	IT-33	26.00	26.00	26.00	26.00	26.00
T34	IT-34	43.00	43.00	43.00	43.00	43.00
T35	IT-35	27.00	27.00	27.00	27.00	27.00
T36	IT-36 (CG Raigarh Haldi-3)	16.00	16.00	16.00	16.00	16.00
T37	IT-37	33.00	33.00	33.00	33.00	33.00
T38	IT-38	49.00	49.00	49.00	49.00	49.00
T39	IT-39	4.00	4.00	4.00	4.00	4.00
T40	IT-40	36.00	36.00	36.00	36.00	36.00
T41	IT-41	39.00	39.00	39.00	39.00	39.00
T42	IT-42	38.00	38.00	38.00	38.00	38.00
T43	IT-43	54.00	54.00	54.00	54.00	54.00
T44	IT-44	42.00	42.00	42.00	42.00	42.00
T45	IT-45	50.00	50.00	50.00	50.00	50.00
T46	IT-46	28.00	28.00	28.00	28.00	28.00
T47	IT-47	31.00	31.00	31.00	31.00	31.00
T48	IT-48	47.00	47.00	47.00	47.00	47.00
T49	IT-49	32.00	32.00	32.00	32.00	32.00
T50	IT-50	37.00	37.00	37.00	37.00	37.00
T51	IT-51	52.00	52.00	52.00	52.00	52.00
T52	Roma	44.00	44.00	44.00	44.00	44.00
T53	Suranjana	35.00	35.00	35.00	35.00	35.00
T54	BSR 2	53.00	53.00	53.00	53.00	53.00

6. Conclusion

The two-season evaluation of 54 indigenous turmeric accessions at Raigarh revealed substantial and internally coherent variation in days to maturity and four vegetative growth traits. Plant height ranged from 74.71 to 134.79 cm, shoots from 2.04 to 6.16, leaves on main shoots from 4.01 to 9.08, and petiole length from 11.39 to 35.18 cm, while maturity ranged from 197.75 to 243.50 days. IT-1 was the most prominent high-growth accession and also the earliest to mature, whereas IT-43 represented the contrasting late-maturing, low-growth phenotype.

The strong accession-level correlations among plant height, shoot number, leaf number, and petiole length, together with their inverse relationships with days to maturity, indicate that vegetative architecture and phenology were strongly coordinated within the evaluated collection. Cross-season correlations were high for all traits, demonstrating substantial consistency of accession ranking between 2021-22 and 2022-23. The supplied CD and CV values further indicate good experimental precision and clear separation among several contrasting accessions.

From a breeding and conservation perspective, IT-1, IT-28, IT-3, IT-39, and IT-11 merit priority for subsequent evaluation because of their consistently strong structural growth, while the contrasting low-growth group may be useful for diversity studies and trait-specific selection. Among the named Chhattisgarh materials, IT-10 showed particularly strong vegetative

performance. However, no accession should be declared superior for overall productivity on the basis of growth alone. Future evaluation should integrate rhizome yield, dry recovery, curcuminoid concentration, disease response, and molecular diversity before recommending accessions for cultivar development or commercial deployment.

7. Practical recommendations for subsequent evaluation

Retain the complete 54-accession collection as a phenotypically diverse regional germplasm resource.

Prioritize IT-1, IT-28, IT-3, IT-39, IT-11 and IT-10 for independent trials incorporating rhizome yield and quality traits. Include contrasting low-growth accessions such as IT-43 and BSR-2 in diversity and trait-association studies rather than discarding them solely because of low vegetative growth.

Conduct multi-location evaluation to determine whether the observed maturity-growth relationship persists across environments.

Combine the present morphological descriptors with molecular markers and rhizome quality measurements for integrated germplasm characterization.

8. Data availability

All numerical observations used in this article were derived from the supplied document titled “Paper 2 Growth”. The complete

accession-wise values for the five traits are reproduced in the supplementary tables of this manuscript, together with the original season-wise and pooled values. No external dataset was merged with the experimental observations.

9. Conflict of interest

No conflict-of-interest statement was provided in the source document; therefore, no additional declaration is made in this data-based manuscript.

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