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Yukta Chavan
M.Sc. Scholar, Department of Plant Physiology, PGI, MPKV, Rahuri, Maharashtra, India

RS Wagh
Cotton Breeder, Cotton Improvement Project, MPKV, Rahuri, Maharashtra, India

DV Deshmukh
Jute Breeder, Cotton Improvement Project, MPKV, Rahuri, Maharashtra, India

VB Shinde
Assistant Sorghum Breeder, Sorghum Improvement Project, MPKV, Rahuri, Maharashtra, India

VR Awari
Assistant Professor Department of Plant Physiology, PGI, MPKV, Rahuri, Maharashtra, India

Corresponding Author:
Yukta Chavan
M.Sc. Scholar, Department of Plant Physiology, PGI, MPKV, Rahuri, Maharashtra, India

Integration of phenology, growth and fibre quality assessment for selection of superior tossa jute (*Corchorus olitorius* L.) Genotypes

Yukta Chavan, RS Wagh, DV Deshmukh, VB Shinde and VR Awari

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Abstract
The present investigation entitled "Phenology, Growth, Fibre Yield and Quality Studies in Tossa Jute (*Corchorus olitorius* L.)" was undertaken during kharif 2024 at the Cotton Improvement Project, MPKV, Rahuri, Maharashtra. Seven genotypes of tossa jute (JRO 204, BROJ-6, JROBA-10, RHRJ-6, NJ-75, JROR-1 and JRO 524) were evaluated under Randomized Block Design (RBD) with three replications. Phenological stages were recorded using the BBCH scale, while growth parameters (plant height, basal diameter, leaf number, leaf area index), fibre yield, and quality traits were studied. Fibre quality was further analyzed at ICAR-NINFET, Kolkata. Significant genotypic variation was observed for all phenological and biometric traits. Early-maturing genotype BROJ-6 reached germination, leaf emergence, stem elongation, flowering, and maturity stages much earlier, but was associated with lower biomass accumulation and fibre yield. In contrast, late-maturing genotypes such as NJ-75, JROBA-10, and JROR-1 exhibited prolonged vegetative growth, taller plant stature, thicker basal stem diameter, higher leaf number, and larger assimilatory surface area. These attributes translated into superior fibre yield and enhanced fibre quality. Plant height, stem girth, leaf traits, and leaf area were found to be positively correlated with fibre yield, supporting the critical role of vegetative vigour in fibre productivity. The study highlights that phenological behaviour strongly governs growth parameters and fibre development in tossa jute, with the BBCH scale providing a reliable tool for standardized phenological assessment. From a practical perspective, late-maturing, vigorous genotypes (NJ-75, JROBA-10, JROR-1) are promising candidates for breeding programs and high-input cultivation strategies, particularly under the sub-montane conditions of Maharashtra, whereas early types may offer advantages in short-season or waterlogging-prone environments.Overall, the findings emphasize the integration of phenology, growth dynamics, and fibre quality assessment in jute improvement and management, enabling the development of high-yielding, quality-enhancing, and climate-resilient jute cultivation strategies.

Keywords: *Corchorus olitorius*, phenology, BBCH scale, growth traits, fibre yield, fibre quality

1. Introduction

Fibre crops occupy an important position in global agriculture as providers of renewable, biodegradable, and eco-friendly raw materials for the textile, packaging, composite, and handicraft industries. Unlike synthetic fibres, natural fibres are sustainable, contributing significantly to climate-smart development and reducing dependency on environmentally harmful products. Among major fibre crops such as cotton, flax, mesta, sunn hemp, and coir, jute holds distinctive importance as an economical and eco-friendly bast fibre crop. It is often referred to as the "golden fibre" owing to its versatility, low production cost, and immense value in sustainable industrial applications. Globally, jute is considered the second most important fibre crop after cotton, particularly in South Asia, where its cultivation sustains rural communities and supports agro-industrial economies (Basu *et al.*, 2004) [4].

The genus *Corchorus*, commonly referred to as jute, comprises several fibrous plant species, of which nine have been reported in India (Sinha *et al.*, 2011) [21]. Among them, *C. olitorius* (Tossa jute) and *C. capsularis* (White jute) are commercially cultivated, both diploids with 2n=14 chromosomes. Tossa jute produces softer, silkier, and stronger fibres of higher market value compared to White jute (Akter *et al.*, 2009; Chowdhury *et al.*, 2001) [2, 6]. However, its susceptibility to multiple biotic and abiotic stresses often limits productivity (Rahman *et al.*, 2021) [18].

Conversely, White jute is more resilient though it provides comparatively inferior fibre quality. Wild relatives serve as important reservoirs of genetic variability, offering potential traits such as drought tolerance, fine fibre characteristics, and disease resistance, which can be exploited through interspecific hybridization to enrich genetic resources (Sinha *et al*., 2011) [21].

Jute cultivation is concentrated in the fertile alluvial plains of India and Bangladesh, extending across nine distinct agro-climatic zones, which differ by rainfall and soil conditions. Optimum jute growth is achieved under a warm and humid monsoon climate, with temperatures of 20-40 °C, relative humidity of 70-80%, and soil pH between 6.0 and 7.5. The majority of jute is grown under rainfed conditions, although low-lying fields also support cultivation (Basu, 1997). High dry matter accumulation rates (25-30 g/m²/day) and substantial radiation-use efficiency highlight its potential for biomass and fibre production (Palit, 1993) [15].

Jute fibres are extracted from the stem, specifically from the phloem or bast tissues, making it a lingo-cellulosic fibre containing cellulose, hemicellulose, and lignin. Retting, the microbial decomposition of pectins and gummy substances, is a critical process distinguishing fibre strands from woody core. Traditional retting methods involve steeping defoliated bundles in stagnant or running water, followed by stripping and fibre extraction through mechanical beating (Majumdar & Day, 1977; Ahmed & Akhter, 2001) [11, 1]. The quality of retting largely determines the fineness, strength, and spinnability of jute fibre (Dasgupta *et al*., 1976) [7].

Jute's utility extends far beyond conventional uses in sacking and packaging. Its adaptability has expanded into high-value industries such as apparel, home textiles, geotextiles, composites, nanocellulose products, and eco-friendly bioplastics. Additionally, its by-products, such as jute sticks, are used in fuel, particle board, and incense manufacturing. Jute cultivation supports sustainable development through soil carbon sequestration, addition of organic matter, and provision of eco-friendly alternatives to synthetic materials. Its alignment with the United Nations' Sustainable Development Goals (SDGs) underscores its role in promoting rural employment, circular economy, and climate-resilient farming.

The growth and productivity of jute are closely linked to its phenological and morphological patterns. Phenology-the study of cyclic and seasonal biological events-helps in understanding critical stages such as germination, vegetative development, flowering, and maturity, which directly influence fibre yield and quality (Meier *et al*., 2009) [12]. Growth traits like plant height, stem diameter, node number, and leaf area index reflect the physiological performance of the crop, while canopy light interception and radiation-use efficiency ultimately determine biomass accumulation (Palit, 1993) [15]. However, despite its agro-economic importance, relatively few studies have systematically examined the interrelationship between phenology, growth parameters, and fibre attributes across genotypes and agro-climatic conditions.

To standardize growth stage documentation, the BBCH scale provides a useful coding system for recording jute phenology uniformly (Meier, 2009) [12]. This facilitates precision in crop management, forecasting, and research communication. Therefore, an integrated understanding of phenological behaviour, growth dynamics, and fibre quality is essential for developing superior genotypes, optimizing agronomic practices, and sustaining the global significance of jute as a versatile and eco-friendly fibre crop.

2. Materials and Methods

The field experiment entitled *"Phenology, Growth, Fibre Yield and Quality Studies in Tossa Jute* (*Corchorus olitorius* L.)*"* was conducted during kharif 2024 at Cotton Improvement Project, MPKV, Rahuri, Ahilyanagar, Maharashtra. Physiological parameters were studied in the Department of Agricultural Botany, MPKV, while fibre quality was analyzed at ICAR-NINFET, Kolkata.

2.1. Experimental Site and Climate

The experimental plot had uniform, well-drained medium black soils. The location lies at 19.38°N latitude, 74.65°E longitude, and 511 m altitude, under the sub-montane zone. During experimentation, maximum temperature ranged from 22.8-32.5 °C (mean 27.6 °C), and minimum from 13.7-23.6 °C (mean 18.6 °C). Mean relative humidity was 79% (morning) and 52% (evening) with a seasonal rainfall of 765.4 mm.

2.2 Experimental Design and Crop Management

Seven tossa jute genotypes-JRO 204, BROJ-6, JROBA-10, RHRJ-6, NJ-75, JROR-1, and JRO 524-were sown on 23rd June 2024. The experiment was laid out in Randomized Block Design (RBD) with three replications. Gross plot size was 6.0 × 4.5 m and net plot size 5.4 × 3.9 m, maintained at 30 cm × 5-7 cm spacing. Fertilizer was applied at 80:40:40 $N:P_2O_5:K_2O$ kg/ha, with half N and full P, K as basal; remaining N top-dressed at 35-40 and 65-70 DAS. Intercultural practices included thinning (15th July), hand weeding, and three irrigations (23rd June, 29th July, 13th August). The crop was harvested on 7th October 2024.

2.3 Observations and Phenology

Five plants per plot were randomly tagged for growth observations (plant height, stem diameter, node number, LAI). Phenological stages were recorded according to the BBCH scale (Hack, 1992). Fibre yield and quality (fineness, strength, colour, bundle properties) were assessed post-harvest.

2.4 Statistical Analysis

Data were analyzed through ANOVA under RBD. Treatment means were compared using CD at 5% level. Correlation and regression were performed to study relationships among phenology and growth traits.

3. Result and Discussion

3.1 Crop Phenology

The data on phenological development of seven jute (*Corchorus olitorius* L.) genotypes, recorded using the BBCH scale, revealed statistically significant differences across all stages (Table 1). Variation among genotypes for principal growth stages such as germination, leaf development, stem elongation, inflorescence emergence, and flowering indicated the influence of genetic constitution and environmental interaction.

For germination, sprouting, and early bud development, genotype NJ-75 required the maximum duration (6 days) compared to BROJ-6 (4 days), which was the earliest to establish seedlings. Earlier germination and rapid establishment confer an advantage under competitive

environments due to faster canopy coverage (Mollah et.al 2019) [14].
During leaf development, NJ-75 again took longer (10-39 DAS) compared with BROJ-6 (7-29 DAS), reflecting genotypic variations in juvenile vigour. Extended leaf development improves assimilatory surface but can delay transition to reproduction. For stem elongation, significant differences were observed. NJ-75 exhibited prolonged elongation (48-65 DAS), while BROJ-6 completed this phase earlier (39-51 DAS). Stem elongation is critical as both plant height and stem thickness directly contribute to fibre production (Ali *et al*., 2002) [3].
Similarly, inflorescence emergence and flowering differed significantly across genotypes. NJ-75 was the latest (65-88 DAS), while BROJ-6 was earliest (54-74 DAS). Delayed flowering tended to extend vegetative growth, thereby enhancing biomass and fibre yield potential. Comparable results were reported in roselle, where high temperatures accelerated phenological stages (Javadzadeh *et al*., 2018) [9]. In jute, differences in flowering and maturity align with earlier findings that time to 50% flowering, fruiting, and maturity varies widely among environments and genotypes (Hassan Kassim *et al*., 2022) [8].
Overall, late-maturing genotypes such as NJ-75 showed prolonged vegetative growth and higher biomass accumulation, while early-types like BROJ-6 progressed rapidly but produced lower biomass and fibre yield.

Table 1: Phenological development influenced by O. Jute genotypes

	Principle growth stages (days)	JRO-204	BROJ-6	JROBA-10	RHRJ 6	NJ-75	JROR-1	JRO 524
1.	**Germination, Sprouting, Bud development**							
01	Beginning of seed imbibition, Beginning of bud swelling (P,V)	1	1	1	1	1	1	1
03	Seed imbibition complete; End of bud swelling (P, V)	2	2	2	2	2	2	2
05	Radicle (root)emerged from seed; Perennating organs forming roots (P, V)	3	2	3	3	3	3	2
06	Elongation of radicle, formation of root hairs and lateral roots	3	3	4	3	4	3	3
07	Coleoptile emerged from caryopsis (G); Hypocotyl with cotyledons or shoot breaking through seed coat (D, M), Beginning of sprouting or bud breaking (P, V)	4	3	4	4	5	4	3
08	Hypocotyl with cotyledons growing towards soil surface (D), Shoot growing towards soil surface (P, V)	4	4	5	4	5	4	4
09	Emergence: Coleoptile breaks through soil surface (G), Emergence: Cotyledons break through soil surface (except hypogeal germination D, M); Emergence: Shoot/leaf breaks through soil surface (D, V); Bud shows green tips (P)	5	4	6	5	6	5	5
2	**Leaf development (main shoot)**							
10	First true leaf emerged from coleoptile (G); Cotyledons completely unfolded (D, M); First leaves separated (P)	8.5	7	9	8	10	8.5	7.75
11	First true leaf, leaf pair or whorl unfolded; First leaves unfolded (P)	10.75	9.25	11	10	12	11	9.75
12	true leaves, leaf pairs or whorls unfolded	12	10.25	14	12	15	13	11
13	true leaves, leaf pairs or whorls unfolded	16	13	17	15	19	16.75	15
19	more true leaves, leaf pairs or whorls unfolded	36	29	38	35	39	37	32.5
3	**Stem elongation, shoot development (main shoot)**							
31	Stem 10% of final length (diameter); 1 node detectable (G)	44	39	48	42	48	45	40
32	Stem 20% of final length (diameter); 2 nodes detectable (G)	46	42	50	45.5	51	48	43
33	Stem (rosette) 30% of final length (diameter); 3 nodes detectable (G), Stages continuous till.	50	47	54	49	55	53	49.5
39	Maximum stem length diameter reached; or more nodes detectable (G 9)	58.5	51	62	57	64.75	61.25	55
4	**Inflorescence emergence (main shoot) / heading**							
51	Inflorescence or flower buds visible; Beginning of heading (G)	60	54	64	60	65.75	62	59
55	First individual flowers visible (still closed); Half of inflorescence emerged (G)	64	58	68	62.5	71	66	60.25
59	First flower petals visible (in petalled forms); Inflorescence fully emerged (G)	68	62	72	66	77	70	65
5	**Flowering (main shoot)**							
60	First flowers open (sporadically)	70	65	74	69	79.75	73	68
61	Beginning of flowering: 10% of flowers open	72	68	75.25	71.5	82	74.5	70
62	20% of flowers open	74	69	76	72	83	75.5	71
63	30% of flowers open	75	71	78	73	85	76	72
64	40% of flowers open	76	72	79	74	86	77	73
65	Full flowering: 50% of flowers open, first petals may be fallen	77.25	74	81	75	88	79	74.75

3.2 Growth and Development

Significant genotypic differences were observed for plant height, basal diameter, number of leaves, leaf dimensions, and leaf area recorded at 20-day intervals. Growth responses revealed a linear increase up to 80-100 DAS, followed by declines due to senescence.

3.2.1 Plant Height

Plant height increased progressively up to 100 DAS, ranging from 21.96 cm at establishment to 302.4 cm at maturity. NJ-75 consistently recorded maximum height (335 cm at harvest), while BROJ-6 remained the shortest (273 cm). Taller genotypes such as NJ-75 and JROBA-10 demonstrated higher fibre yield potential, confirming earlier reports that plant height correlates positively with fibre yield (Palit *et al*., 1996; Kumar *et al*., 2014; Ali *et al*., 2002) [15, 10, 3].

3.2.2 Basal Stem Diameter

Stem basal diameter followed a similar trend, significantly increasing with crop age. NJ-75 exhibited thicker stems (2.35 cm at 100 DAS), while BROJ-6 showed the thinnest

(1.84 cm). A larger stem girth contributes directly to superior fibre yield and quality by providing more fibre bundles (Miah *et al*., 2020) [13]. These results corroborate findings that basal diameter is a key determinant of fibre productivity (Sobhan & Khatun, 1982) [22].

3.2.3 Number of Leaves per Plant
Leaf number varied significantly, peaking around 80 DAS before declining due to leaf senescence. NJ-75 recorded the highest leaf count (254 at 80 DAS), while BROJ-6 was lowest (192). Higher leaf number enhances photosynthetic capacity and assimilate partitioning, supporting fibre production-a finding consistent with Roy *et al*. (2004) [20].

3.2.4 Leaf Dimensions (Length and Breadth)
Leaf length and breadth followed similar increasing trends until 80 DAS, followed by reductions due to drying and curling. NJ-75 had the largest leaves across all growth stages. Roy and Ghosh (2004) [19] reported significant positive associations between leaf morphological traits, plant vigour, and fibre yield, supporting the present findings.

3.2.5 Leaf Area: Leaf area differed significantly among genotypes, with NJ-75 attaining the highest leaf area at all stages (e.g., 168.8 dm² at 60 DAS). Declines post 80 DAS corresponded with onset of senescence. Larger leaf area enhances canopy photosynthesis and biomass accumulation, ultimately correlating with fibre yield (Palit & Bhattacharya, 1987) [16].

The present study demonstrated that phenology and growth traits varied significantly among tossa jute genotypes, with NJ-75 performing superiorly in terms of plant height, basal diameter, leaf production, and assimilatory surface area. These traits were positively correlated with fibre yield and quality. Early maturing genotypes (e.g., BROJ-6), though quicker to flower, showed reduced vegetative growth and lower biomass accumulation, resulting in comparatively lower fibre potential.

The results validate earlier findings that phenology determines resource partitioning (Javadzadeh *et al*., 2018; Hassan Kassim *et al*., 2022) [9, 8], and growth characters such as plant height, stem girth, and leaf traits are critical predictors of fibre yield in jute (Ali *et al*., 2002; Kumar *et al*., 2014; Roy & Ghosh, 2004; Miah *et al*., 2020) [3, 10, 19, 13].

Thus, genotypes with extended vegetative growth and robust morphology (NJ-75, JROBA-10, JROR-1) appear superior candidates for high-yielding fibre breeding and management strategies in tossa jute.

Table 2: Growth and development characters influenced by O. Jute genotypes at various stages of growth

Plant Height (cm)	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
JRO-204	21.67	90.33	164.67	224.00	297.00
BROJ-6	16.33	77.67	140.33	207.00	273.33
JROBA-10	26.33	102.00	172.33	243.33	326.00
RHRJ- 6	18.67	85.33	155.67	218.27	295.33
NJ-75	30.67	111.67	187.40	254.00	335.00
JROR-1	23.00	95.00	168.67	232.00	313.00
JRO-524	17.07	78.33	147.00	213.27	277.33
Mean	21.96	91.47	162.29	227.41	302.42
SE(m)±	0.552	1.113	1.734	1.975	1.676
CD at 5%	1.703	3.432	5.345	5.925	5.034
Basal diameter (cm)					
JRO-204	0.58	0.84	1.19	1.61	2.09
BROJ-6	0.44	0.66	1.07	1.35	1.84
JROBA-10	0.63	0.96	1.31	1.74	2.24
RHRJ- 6	0.51	0.81	1.14	1.53	2.04
NJ-75	0.70	1.06	1.41	1.77	2.35
JROR-1	0.61	0.83	1.25	1.69	2.18
JRO-524	0.47	0.68	1.08	1.42	1.95
Mean	0.56	0.83	1.21	1.59	2.09
SE(m)+	0.024	0.032	0.026	0.040	0.017
CD at 5%	0.073	0.099	0.080	0.124	0.054
No. of leaves					
JRO-204	6.33	47.00	120.33	215.33	114.00
BROJ-6	5.33	37.00	83.33	192.33	72.00
JROBA-10	6.67	58.33	132.00	238.33	122.33
RHRJ- 6	6.33	47.33	109.67	206.67	107.33
NJ-75	8.00	65.33	143.67	254.33	124.33
JROR-1	6.33	51.00	126.00	222.33	117.66
JRO-524	5.67	43.33	94.66	198.33	103.33
Mean	6.38	49.90	115.66	218.23	108.71
SE(m)+	0.384	2.007	1.556	2.211	3.136
CD at 5%	1.186	6.187	4.796	6.613	9.433
Leaf Length(cm)					
JRO-204	6.47	13.03	18.23	16.47	15.83
BROJ-6	5.73	9.57	14.23	15.20	12.17
JROBA-10	7.40	14.47	21.73	19.30	16.77
RHRJ- 6	6.07	11.63	17.50	17.53	14.43
NJ-75	8.23	15.43	22.93	22.77	17.73

JROR-1	7.07	13.36	19.87	17.56	15.47
JRO-524	6.10	10.66	16.23	15.76	13.30
Mean	6.72	12.59	18.67	17.80	15.10
SE(m)+	0.155	0.283	0.257	0.650	0.249
CD at 5%	0.470	0.872	0.792	2.003	0.768
Leaf Breadth					
JRO-204	3.47	7.67	8.78	7.62	6.20
BROJ-6	2.78	6.20	7.13	6.72	4.13
JROBA-10	3.85	7.87	9.58	8.92	7.77
RHRJ- 6	3.58	7.38	7.87	8.20	5.72
NJ-75	4.41	8.53	11.17	9.55	7.83
JROR-1	4.11	7.68	9.71	8.50	6.90
JRO-524	3.21	6.56	7.17	7.21	5.48
Mean	3.63	7.41	8.78	8.10	6.29
SE(m)+	0.197	0.334	0.297	0.222	0.281
CD at 5%	0.607	1.031	0.915	0.685	0.867
Leaf area (dm2)					
JRO-204	14.75	65.69	106.12	82.70	64.81
BROJ-6	10.53	39.91	67.08	67.78	33.15
JROBA-10	18.82	75.21	137.49	113.68	86.01
RHRJ- 6	14.32	56.78	90.87	94.97	54.54
NJ-75	23.96	82.56	168.81	150.88	91.69
JROR-1	19.19	67.82	134.33	98.64	70.58
JRO-524	12.97	46.32	77.43	75.05	48.26
Mean	16.36	62.04	111.73	97.67	64.14
SE(m)+	0.691	2.428	1.788	2.013	3.183
CD at 5%	2.131	7.482	5.510	6.204	9.810

4. Conclusion

The present investigation on *Corchorus olitorius* L. genotypes revealed that both phenological behaviour and growth traits exert a significant influence on fibre yield and quality. Marked variation was observed among the seven genotypes studied, indicating ample genetic diversity for selection and crop improvement. Late-maturing genotypes such as NJ-75, JROBA-10, and JROR-1 exhibited prolonged vegetative growth, taller plant stature, greater stem girth, higher leaf number, larger leaf area, and delayed flowering, ultimately supporting greater biomass accumulation and superior fibre productivity. In contrast, early-maturing genotypes like BROJ-6 attained faster phenological transitions but were associated with reduced vegetative performance and comparatively lower fibre yield. The study highlights that plant height, basal diameter, leaf production, and assimilatory surface area are critical determinants of fibre yield and quality, aligning with their strong positive correlations observed in earlier investigations. Phenological recording through the BBCH scale provided a standardized and precise measure for comparing growth stages across genotypes, enhancing the accuracy of developmental analysis. From a practical perspective, the findings suggest that late-maturing, vigorous genotypes (e.g., NJ-75) are promising for breeding programs and high-yielding cultivation strategies under Maharashtra's sub-montane agro-climatic conditions. Meanwhile, early-maturing types may still be useful in environments with shorter growing seasons or where waterlogging risks encourage rapid crop turnover. Overall, this study underscores the importance of integrating phenological monitoring, growth dynamics, and fibre quality assessment in jute improvement programs. Such an approach can guide the selection of superior genotypes and refinement of crop management practices, thereby contributing to enhanced fibre productivity, rural livelihoods, and sustainable jute cultivation.

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