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Research Article

Genotypic Variability and Correlation Studies in Pod and Seed Characteristics of *Pongamia pinnata* (L.) Pierre in Orissa, India

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Pongamia pinnata (L.) Pierre is a fast growing leguminous tree with high potential for oil seed production. Fifty-three candidate plus trees (CPTs) of *Pongamia pinnata* were selected from different locations in Orissa, India, on the basis of their seed and pod characteristics to identify suitable seed source with high oil content for production of quality planting seedling for use in afforestation programs. All the CPTs showed significant variation among themselves in respect to their pod and seed characters. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) estimates were high for pod thickness, seed thickness, 100-pod weight, and 100-seed weight. High heritability values accompanied by high genetic advance for 100-seed weight (96.1%, 59.6) and 100-pod weight (90.9%, 37.3) indicated additive gene action. High estimates of genotypic correlations than the corresponding phenotypic correlations indicated the presence of strong inherent association between pod length and pod breadth; 100-pod weight, and pod thickness; 100-pod weight and seed length; 100-seed weight and 100-pod weight. Seed length, seed breadth, seed thickness, 100-pod weight and 100-seed weight had significant positive correlation with each other, and these characters should be considered as effective parameters to select CPTs for different agroforestry programs.

1. Introduction

Self-reliance in energy is vital for overall economic development of India and other developing countries. The recent oil crises and depleting fossil fuel reserves have rekindled interest in promotion of tree-borne oil seed species. Amongst the many plant species, *Pongamia pinnata*—a fast growing leguminous tree that has a high potential for high oil seed production and ability to grow on marginal lands—supports its cultivation as a potential biofuel crop for biodiesel industry [1].

Pongamia pinnata (L.) Pierre is an arboreal legume belonging to subfamily Papilionoideae. The medium size tree is indigenous to the Indian subcontinent and South-East Asia and has been successfully introduced to humid tropical regions including parts of Australia, New Zealand, China, and United States. The mature tree can withstand water logging and slight frost and is highly tolerant to salinity, and it can be grown along seashores with its roots surviving in saltwater. In its natural habitat, the species tolerates a wide range of temperature that is up to 50°C. *P. pinnata* had also a positive bioameliorative effect with contributions to soil nitrogen, phosphorous, potassium, and organic carbon. It is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Its root, bark, leaves, sap, and flower have medicinal properties and have effect on wide array of organisms including insects, pests, nematodes, and molluses [2–5]. As the plant is an efficient and potential biodiesel crop, it is necessary to establish extensive plantations comprising elite varieties of these trees, with higher potential to produce oil seeds.

The effectiveness of tree improvement programme depends upon the nature and magnitude of existing genetic variability and also on the degree of transmission of traits

Table 1: Plants collected from different locations of Orissa, India, for diversity study.

Sl. no.	Locations	GPS reading		Altitude (m)	Climatic parameter		N
		Latitude (°N)	Longitude (°W)		Tm (°C)	Rn (cm)	
1	Bargaon, Shambalpur	22°07′	84°03′	450	27.0–32.0	60–100	25
2	Kalimati, Shambalpur	21°30′	83°59′	450	27.0–32.0	60–100	15
3	Ghatikia 1st population, Bhubaneswar	20°08′	85°58′	220	25.0–29.5	200–600	50
4	Ghatikia 2nd population, Bhubaneswar	20°08′	85°58′	220	25.0–29.5	200–600	26
5	Kosola, Anugul	21°02′	85°26′	220	25.0–39.5	200–400	65
6	Dera, Anugul	21°16′	85°29′	220	25.0–39.5	200–400	20
7	Katada, Anugul	21°01′	85°27′	220	25.0–39.5	200–400	25

Tm: Annual temperature; Rn: Annual rainfall; N: Number of individuals collected.

or heritability [6] as because genetic variation is a basic requirement for long-term stability of forest ecosystem and maintenance of diversity. Genetic improvement of this crop to achieve higher yield in terms of its oil content is an important breeding objective. Selection of candidate plus trees (CPTs) on the basis of oil content is not effective as this character is polygenic controlled. Therefore, selection on the basis of component traits having high genotypic coefficient of variation (GCV), high heritability, along with high genetic advance could be more effective to select plants for increasing the oil content of *Pongamia pinnata*. The present investigation is to assess the genetic variability among the plants of *P. pinnata* grown in different locations of Orissa, India, keeping the aforesaid objective in mind.

2. Material and Methods

Extensive survey was conducted in seven populations across three different ecogeographical regions of Orissa, India, for screening and selection of outstanding CPTs (candidate plus trees) of *Pongamia pinnata* (Table 1). Plantation was made in different ecogeographical regions in 1983. According to Kaushik et al. [7], 100-pot weight and 100-seed weight were the important component traits of oil content with high genotypic coefficient variability and heritability value and were considered to select CPTs plant of *P. pinnata*. On considering the report of Kaushik et al. [7], out of the 111 selected plants, 53 CPTs were identified based on the morphometric and qualitative traits. Care was taken to collect the dry pods directly from the selected trees. Pod and seed characters, namely, length (mm), breadth (mm), thickness (mm) and weight (g), were recorded for all the genotypes for two consecutive years in the months of May-June. Hundred pods of each CPT (three replications) were taken, and average was computed for the pod and seed characters. Locations 1 and 2 were the same climate and about 600 kms from coastal belt. Locations 3 and 4 were in the coastal belt about 50 kms from sea. Locations 5 and 6 were same climate and about 200 Kms from coastal belt. One hundred eleven individuals of *Pongamia pinnata* across the seven populations were selected (Table 1).

Analysis of variance was carried out to estimate PCV (phenotypic coefficient of variation), GCV (genotypic coefficient of variation), broad sense Heritability, and genetic advance [8]. The phenotypic and genotypic correlations between pairs of characters were calculated [9].

3. Results and Discussion

The result revealed that out of 111 plants, 53 plants were marked as a candidate plus trees (Table 2) according to Kaushik et al. [7]. They reported that 100-pod weight and 100-seed weight were the important component traits of oil content with high genotypic coefficient variability (GCV) and heritability value in *P. pinnata*. The analysis of variance showed that there was significant variation among the fifty-three candidate plus trees of *Pongamia pinnata* with respect to pod and seed characters (Table 3). The maximum pod length was observed in CPT-32 and minimum in CPT-35. Out of 53 CPTs, CPT-28 showed maximum 100-pod weight (488.20 g), whereas CPT-10 recorded minimum 100-pod weight (230.60 g). The maximum seed length was noticed in CPT-30 and minimum in CPT-10. 100-seed weight was found to be maximum in CPT-25 (177.40 g) and minimum in CPT-17 (77.29 g).

The extent of variability present in the pod and seed characters is shown in Table 3. The maximum range of variation was observed for 100-pod weight followed by 100-seed weight, pod length, seed length, pod breadth, seed breadth, seed thickness, and pod thickness. The phenotypic, genotypic, and environmental variances for pod and seed characters are presented in Table 4. Phenotypic variances (σ^2p) were found to be greater than the corresponding genotypic variances (σ^2g) for all the characters indicating that the expressions of these characters were influenced by the environmental factors. Phenotypic and genotypic variances were high for 100-pod weight (3510.0 and 3193.18) and 100-seed weight (2649.16 and 2613.79), moderate for pod length, and low for others. Similar finding was also reported by Siddiqui et al., [4] in *Terminalia* species. Genetic analysis like phenotypic coefficient variation (PCV), genotypic coefficient variation (GCV), heritability (h^2), and genetic advance (GA) revealed that PCV was higher than the corresponding GCV for all characters (Table 4), indicating that all the characters had interacted with the environment to some degree. High PCV and GCV (>15%) were observed in case of pod thickness, seed thickness, 100-pod weight, and 100-seed weight.

Table 2: Mean performance of CPTs (candidate plus trees) variation for pod and seed trait in *Pongamia pinnata*.

Candidate plus tree (CPTs)	Individuals code	Pod traits				Seed traits			
		Length (mm)	Breadth (mm)	Thickness (mm)	100-pod weight (g)	Length (mm)	Breadth (mm)	Thickness (mm)	100-seed weight (g)
CPT-1	Kosola-1	53.76	25.12	8.78	251.72	23.24	12.35	6.71	82.8
CPT-2	Kosola-12	55.27	21.73	5.90	290.46	18.53	12.77	4.53	107.4
CPT-3	Kosola-14	55.46	24.04	6.23	258.13	15.86	13.33	4.96	90.03
CPT-4	Kosola-17	55.24	24.23	5.95	245.43	20.38	10.66	4.92	95.833
CPT-5	Kosola-19	55.32	17.93	7.83	270.3	22.23	10.08	5.46	118.03
CPT-6	Kosola-20	50.83	24.62	7.67	253.27	20.56	12.53	5.53	95.8
CPT-7	Kosola-24	55.07	20.42	6.76	237.8	19.73	13.03	5.01	88.4
CPT-8	Kosola-32	47.76	20.06	10.05	255.9	20.66	12.30	8.23	94.1
CPT-9	Kosola-36	50.03	20.50	6.91	241.16	19.33	12.26	5.22	88.2
CPT-10	Kosola-37	56.63	24.73	7.54	230.6	19.67	12.45	6.12	80.90
CPT-11	Kosola-45	59.23	20.08	6.87	258.9	19.96	12.93	4.89	92.90
CPT-12	Kosola-46	49.77	21.56	7.76	260.7	19.77	13.83	5.94	97.07
CPT-13	Kosola-55	55.71	18.67	8.47	274.23	19.85	12.19	6.51	100.8
CPT-14	Kosola-56	53.26	18.49	8.65	322.1	20.36	12.58	6.78	137.80
CPT-15	Kosola-59	40.08	18.35	7.83	363.2	20.41	13.57	5.83	171.07
CPT-16	Kosola-60	43.53	18.76	11.63	310.8	19.43	10.08	8.96	104.8
CPT-17	Kosola-61	52.97	20.47	7.79	274.2	20.05	13.14	5.91	77.8
CPT-18	Kosola-63	50.35	20.13	6.91	324.1	23.16	13.75	5.02	105.5
CPT-19	Dera-66	50.43	19.85	6.86	232.4	19.28	12.63	4.98	102.8
CPT-20	Dera-69	49.19	22.52	6.47	374.02	20.13	14.79	5.04	168.63
CPT-21	Dera-70	41.87	23.28	6.94	329.4	19.75	13.52	5.13	166.63
CPT-22	Dera-72	50.56	24.65	7.89	358.6	19.66	15.73	6.06	174.06
CPT-23	Katada-76	60.21	27.02	5.85	357.03	19.93	12.86	4.11	136.20
CPT-24	Katada-77	46.81	20.78	5.68	299.07	23.27	14.23	4.09	110.2
CPT-25	Katada-78	58.97	26.53	4.98	353.6	19.83	13.47	4.01	177.4
CPT-26	Bargao*n*-1	60.15	20.31	6.84	380.5	25.34	16.13	5.08	154.9
CPT-27	Bargao*n*-2	52.58	23.17	6.76	298.5	19.25	14.76	5.23	90.5
CPT-28	Bargao*n*-5	62.03	22.81	7.95	488.2	21.46	16.36	5.88	153.06
CPT-29	Bargao*n*-10	48.69	18.76	8.73	352.8	21.39	14.27	6.92	125.16
CPT-30	Bargao*n*12	55.63	22.19	5.96	311.5	28.15	14.43	4.57	126.83
CPT-31	Kalimat*i*-4	45.37	20.43	5.82	261.2	19.72	13.96	4.36	81.2
CPT-32	Kalimat*i*-5	39.88	19.69	6.97	276.4	19.93	12.82	5.44	87.8
CPT-33	Ghatikia 1st plot-1	52.13	24.51	10.77	481.1	24.68	16.59	8.17	172.6
CPT-34	Ghatikia 1st plot-3	49.47	22.07	10.85	355.4	19.62	16.23	7.96	135.2
CPT-35	Ghatikia 1st plot-6	66.04	26.36	8.72	348.2	21.23	17.55	6.76	83.8
CPT-36	Ghatikia 1st plot-8	50.73	23.26	8.93	341.5	21.51	15.46	6.33	83.6
CPT-37	Ghatikia 1st plot-10	53.32	21.45	9.82	361.4	20.45	15.38	7.54	85.5
CPT-38	Ghatikia 1st plot-11	51.16	22.82	8.64	378.2	20.42	15.51	6.66	91.5
CPT-39	Ghatikia 1st plot-17	51.22	21.63	10.76	386.8	20.52	14.15	7.86	92.6
CPT-40	Ghatikia 1st plot-22	52.06	21.83	7.92	340.2	21.23	15.72	5.81	81.5

Table 2: Continued.

Candidate plus tree (CPTs)	Individuals code	Pod traits				Seed traits			
		Length (mm)	Breadth (mm)	Thickness (mm)	100-pod weight (g)	Length (mm)	Breadth (mm)	Thickness (mm)	100-seed weight (g)
CPT-41	Ghatikia 1st plot-23	50.64	20.33	9.66	352.6	21.14	15.23	7.74	105.4
CPT-42	Ghatikia 1st plot-26	51.82	21.06	8.58	301.7	22.33	17.05	6.26	82.32
CPT-43	Ghatikia 1st plot-29	52.01	22.24	9.30	366.2	24.13	13.27	7.04	95.8
CPT-44	Ghatikia 1st plot-33	51.93	21.75	9.43	310.5	22.82	13.53	6.94	90.4
CPT-45	Ghatikia 1st plot-34	61.15	25.63	8.96	388.4	19.95	14.87	6.82	115.5
CPT-46	Ghatikia 1st plot-42	50.45	22.37	8.65	343.4	23.17	14.33	6.41	99.5
CPT-47	Ghatikia 1st plot-50	52.23	20.03	10.27	323.8	23.22	12.95	8.05	99.1
CPT-48	Ghatikia 2nd plot-4	46.57	20.26	6.89	279.2	22.15	12.82	5.11	81.6
CPT-49	Ghatikia 2nd plot-8	46.43	20.35	7.56	291.1	21.76	13.16	5.13	81.5
CPT-50	Ghatikia 2nd plot-9	48.25	21.97	7.83	276.1	22.13	13.43	6.24	82.63
CPT-51	Ghatikia 2nd plot-10	45.63	22.13	5.98	285.4	22.25	13.36	4.22	84.63
CPT-52	Ghatikia 2nd plot-19	48.33	22.17	7.74	288.3	22.03	13.67	5.36	83.73
CPT-53	Ghatikia 2nd plot-20	47.51	21.33	8.87	284.9	20.23	13.55	6.42	79.73
Grand Mean		51.65	21.83	7.91	3.14	20.45	13.80	5.96	107.41
SE		2.59	1.52	0.71	14.53	1.15	0.99	0.39	4.85
CD at 5%		5.15	3.01	1.41	28.77	2.28	1.94	0.77	9.62

Table 3: Analysis of variance and phenotypic variability of pod and seed characters of *P. pinnata*.

Characters	Degree of freedom	Genotype MSS	*F*-Value	Mean	Range	SE	CD at 5%
Pod length (mm)	52	87.05	8.62**	51.66	39.88–66.04	2.6	5.15
Pod breadth (mm)	52	14.6	4.24**	21.84	17.93–27.02	1.52	3.01
Pod thickness (mm)	52	6.99	9.27**	7.91	4.98–11.63	0.71	1.41
100-pod weight (g)	52	9896.33	31.24**	314.05	230.60–488.20	14.53	28.77
Seed length (mm)	52	20.96	10.57**	20.46	14.93–28.15	1.15	2.28
Seed breadth (mm)	52	7.71	5.33**	13.8	10.08–17.56	0.98	1.94
Seed thickness (mm)	52	4.39	19.59**	5.97	4.01–8.96	0.39	0.77
100-seed weight	52	2649.0	74.90**	107.41	7.29–177.40	4.86	9.62

** significant at 1% level.

The rest four characters exhibited low PCV and GCV (<15%). Heritability was high (>80%) for 100-seed weight (96.10%), 100-pod weight (90.97%), and seed thickness (86.11%). Burton [10] suggested that the study of GCV together with heritability estimate could give the best picture of the success to be achieved through selection. Such high levels of heritability may be due to the control of additive gene action in expression of these characters. Pod length, pod thickness, and seed length had moderate heritability (60–80%). Pod breadth and seed breadth showed low heritability (<60%) indicating that these two characters were controlled by nonadditive type of gene action. Though heritability estimates give useful indication of the relative values of selection based on phenotypic expression, it does not give more reliable conclusion unless genetic gain under selection is taken into consideration along with heritability.

The present study indicated that the genetic advance ranged from 13.11% to 55.49%. The high heritability accompanied by high genetic advance in 100-seed weight may be due to additive type of gene action. High values of genetic

Table 4: Phenotypic and genotypic analysis of pod and seed characters of *P. pinnata*.

Characters	Phenotypic variance	Genotypic variance	Error variance	GCV (%)	PCV (%)	h2 (%)	GA (5%)	GA (mean %)
Pod length (mm)	35.76	25.64	10.11	11.58	9.8	71.72	8.84	17.1
Pod breadth (mm)	7.17	3.72	3.45	12.26	8.83	51.91	2.86	13.11
Pod thickness (mm)	2.83	2.08	0.75	21.27	18.22	73.37	2.54	32.15
100-pod weight (g)	3150	3193.18	316.82	18.86	17.99	90.97	111.03	35.35
Seed length (mm)	8.3	6.32	1.98	14.09	12.29	76.13	4.52	22.09
Seed breadth (mm)	3.24	2.09	1.15	13.62	10.47	59.06	2.29	16.57
Seed thickness (mm)	1.61	1.39	0.22	21.29	19.76	86.11	2.25	37.77
100-seed weight	2649.16	2613.79	35.37	28.03	27.48	96.1	59.61	55.49

Table 5: Phenotypic (rp) and genotypic (rg) correlation coefficients between different pod and seed characters of *P. pinnata*.

Characters		Pod breadth	Pod thickness	100-pod weight	Seed length	Seed breadth	Seed thickness	100-seed weight
Pod length	rp	0.329*	−0.098	0.176	−0.21	0.193	−0.055	0.047
	rg	0.563**	−0.071	0.210	−0.051	0.237	−0.066	0.031
Pod breadth	rp		−0.091	0.192	−0.164	0.218	−0.126	0.107
	rg		−0.223	0.274*	−0.253	0.397**	−0.152	0.181
Pod thickness	rp			0.301*	0.157	0.124	0.855**	−0.085
	rg			0.372**	0.224	0.210	1.055	−0.089
100-pod weight	rp				0.143	0.433**	0.348*	0.561**
	rg				0.297*	0.792**	0.308*	0.632**
Seed length	rp					0.383**	0.033	−0.019
	rg					0.121	0.241	−0.095
Seed breadth	rp						−0.026	0.244
	rg						0.269	0.209
Seed thickness	rp							−0.091
	rg							−0.052

*, ** significant at 5% and 1% levels, respectively.

advance are indicative of additive gene action involved in the expression of various polygenic traits, and low values are of nonadditive gene action [10, 11]. The correlation study (Table 5) among the pod and seed characters revealed that pod length had positive significant correlation with pod breadth and negative correlation with pod thickness, seed length, and seed thickness both at phenotypic level (rp) and genotypic level (rg). The pod length had positive nonsignificant correlations with 100-pod weight, seed breadth, and 100-seed weight. Pod breadth showed significant positive correlation with 100-pod weight and seed breadth at genotypic level and nonsignificant positive correlation with 100-seed weight. Pod thickness had significant positive correlation with 100-pod weight but negative correlation with 100-seed weight both at genotypic and phenotypic levels. Significant positive correlation of 100-pod weight with seed length, seed breadth, seed thickness, and 100-seed weight at genotypic level shows that genetic improvement in 100-pod weight is likely to improve all the seed characters. 100-seed weight exhibited negative correlation with pod thickness, seed length, and seed thickness.

Summing up, these relationships indicate that 100-pod weight, seed length, seed breadth, seed thickness, and 100-seed weight have significant positive correlations with each other. The result showed that the genotypic correlations are higher than the corresponding phenotypic correlations which indicate the presence of strong inherent association between pod length and pod breadth, 100-pod weight and pod thickness; 100-pod weight and seed length, 100-seed weight and 100-pod weight.

In conclusion, the results of this investigation revealed that significant differences exist among the candidate plus trees on the basis of pod and seed characters of plants grown within seven populations. Further genetic improvement of CPTs for pod and seed characters stands a high chance. 100-pod weight and 100-seed weight had significant positive correlation with each other, and these two characters could be considered as effective parameters in selection of candidate plus trees for agroforestry program. CPT-28 had high pod weight, and CPT-25 had high seed weight and plantation of these two clones as high oil yielder may be suggested for different agroforestry system.

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