



## Research Article

## Variation in morphometric characters, germination and oil content of *Terminalia bellirica* (Gaertn.) Roxb. seeds collected from various provenances of Odisha, India

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### Abstract

The wide distribution of *Terminalia bellirica* in natural forests of Odisha has a good opportunity to identify better genotypes with higher oil yielding potential. The study related to variation in oil content, morphometric characters and germination of *Terminalia bellirica* (Gaertn.) Roxb. seeds was carried out in nine provenances viz. Deogan, Bolangir Kasturi Bahal, Narada, Kantamal, Jeypore, Gunupur, Kuchinda and Ghatikia of Odisha (India) keeping in the importance of the seed oil for biodiesel production, soap industry and medicinal values. *T. bellirica* is widely distributed in Odisha with gregarious fruiting of which most of the fruits remain unused except used as myrobalan for medicinal purposes. It revealed that Kantamal provenance expressed highest fruits length (3.87cm) and 100 fruit weight (1340.17gm), 100 seed weight(649.05gm) and 100 kernel weight(99.43gm) with maximum oil yield which can be taken up for further improvement study. However, the progeny testing at nursey level was also found to have the same provenance performing best for germination and seedling characters.

**Keywords:** Morphometric, Germination, Oil content, Provenances, Seeds, *Terminalia bellirica*

### INTRODUCTION

Among the bio-energy, plant route is considered very promising because of its renewable nature and sustained production with low cost maintained. Bio-diesel produced from plants yielding oil is fast emerging as a viable alternative to petrol diesel, particularly in the face of its diminishing supply and the resulting steep increase in price (Demirbas *et al.*, 2016). Because of the heavy requirement of edible oil, non-edible oil yielding plants are considered ideal for Indian condition for the production of biodiesel (Chhetri *et al.*, 2008). India has many tree-borne oilseeds of which *Terminalia bellirica* (Gaertn.)Roxb. has a lot of potentials (Sarin *et al.*, 2010; Marwaha *et al.*, 2019; Rudreshaiah, 2020). *T. bellirica* is commonly known as

beleric myrobalan and locally called 'Bahada' belonging to family Combretaceae. It is a deciduous tree of about height 20-30 m and 2-3 m in girth distributed throughout the Indian dry and moist deciduous forests, Srilanka, and South East Asia up to an elevation of 1200 meters in a wide range of ecologies. The fruits are ovoid grey drupes and seeds are used as aphrodisiac and oil extract from the seed pulp is used in the treatment of rheumatism (Deb *et al.*, 2016), leucoderma and alopecia. Modern investigations have also proved the laxative activity of the oil (Chatterjee, 2000; Ahn, 2002).

The oil extracted from the seed of *T. bellirica* was also found to be a potential source for biodiesel extraction (Sarin, 2010) and also in soap industries. Odisha lies in the tropical zone between latitudes of 17° 47' N to

22° 34' N and longitudes 82° 22' E to 87° 29' E. It has a recorded forest area of 58,136 km<sup>2</sup> which is 37.34 % of the total geographical area of the state. Odisha has 18 forest types belonging to 4 forest type groups, i.e. Tropical semi-evergreen, Tropical dry deciduous, Tropical moist deciduous and Littoral and swamp forest. It is well established that many tree species with a wide range of geographical diversity exhibit physiological, morphological, biochemical and genetic variations as an adaptation to varying environmental condition (Prativa,2013). *T. bellirica* trees growing in various provenances also show variation in seeds, seedling traits and oil content (Salami, and Akinyele, 2015; Gupta *et al.*, 2016; Sharma *et al.*,2016;). It is an important NTFP of Odisha and widely distributed throughout the state. Considering the importance of the variability in seed characters and oil content of *T. bellirica* seeds from different provenances of Odisha, the present study was carried out to find out the variation in seed morphometric characters, oil content, germination and seedling traits of this tree.

**MATERIALS AND METHODS**

Selection of sample trees was made in each of the provenances of *T. bellirica* (Gaertn.) Roxb. where healthy trees of the nearly same diameter at breast height (40-50cm) were considered and other morphometric characters like tree height, crown area, 100 fruit weight and fruit length were also taken into consideration. Five sample trees were collected from each provenance. Basing on the higher values of morphometric characters like 100 fruit weight and fruit length ( Kaushik *et al.*, 2007 ) 15 Candidate Plus Trees

(CPTs) were identified from each provenance and the details of the provenances of the state Odisha of India are given in Table 1.

Three samples of fruits with 100 fresh and fully ripened matured fruits per sample were collected from each CPT. The fruit length (cm) and fruit width (cm) were measured using Vernier calliper, 100 fruits weight (gm) was measured by using digital balance and oil was extracted from the dried seed kernels(50 g) by Soxhlet apparatus using petroleum ether (40°C – 60°C ) as solvent system. The oil content (%) was recorded on the dried kernel weight basis as -

$$\text{Percentage of oil content} = \frac{W_2 - W_1}{50} \times 100 \dots \text{Eq. 1}$$

W<sub>1</sub>(g)- Weight of the empty flask

W<sub>2</sub>(g)- Weight of flask with oil

The progeny testing was carried out in the nursery of College of Forestry, OUAT at Bhubaneswar having average high temperature ( 32.6°C), average low temperature ( 22.4°C) , annual rainfall (1492 mm) and average relative humidity (70%). For progeny testing from each CPT randomly 3 samples with 100 fresh and fully matured fruits per sample were collected. The fruits were kept in water for 24 hours, and then seeds were extracted. Seeds were treated with Diathane M-45 (3g/kg of seed) and then sown in poly-pots filled with nursery mixture prepared with soil, sand and FYM mixture of ratio 2:1:1. The number of seed germinated daily up to 30 days after sowing, Seedling length (cm), Fresh seedling biomass(g), Oven dry

**Table 1.** Provenance details of *Terminalia bellirica* in Odisha with their climatic and edaphic conditions.

Provenance	Block	District of Odisha	Altitude (mt.)	Annual Rainfall (mm)	Avg. Temp. (°C) (Max. -Min.)	pH	N	P	K	OC
Deogan	Deogan	Bolangir	383	1229.47	44-8	4.5	M	M	M	M
Bolangir	Bolangir	Bolangir	383	1229.47	44-8	4.3	M	M	M	M
Kasturi Bahal	Kishorenagar	Angul	197	1421	45-10	6.7	L	M	L	L
Natada	Talcher	Angul	875	1421	47-10	6.0	L	M	L	L
Kantamal	Kantamal	Boudh	144	1510	44-10	5.5	L	M	L	L
Jeypore	Jeypore	Koraput	870	1604	38-5	4.7	M	M	L	M
Gunupur	Gunupur	Rayagada	207	1340	40-5	5.2	M	M	M	M
Kuchinda	Kuchinda	Sambalpur	135	1638	47-11.8	5.5	M	M	M	M
Ghatikia	Bhubaneswar	Khurda	45	1505	45.2-8.2	5.3	L	L	L	L

\* Rating chart of soil characteristics

Nutrient	Low (L)	Medium (M)	High (H)
Organic carbon (OC)	< 0.5 %	0.5 - 7.5%	> 0.75%
Available nitrogen ( N)	< 240Kg/ha	240- 480kg/ha	> 480Kg/ha
Available Phosphorus (P)	< 11.0 Kg/ha	11 – 22 Kg/ha	> 22 Kg/ha
Available potassium ( K)	< 110Kg/ha	110-280Kg/ha	> 280Kg/ha

seedling Biomass(g) were recorded after 90 days of sowing. Basing on the number of seeds germinated, Germination percentage (%), Mean daily germination (MDG), Peak value (P.V.), Germination Value (G.V.) were calculated as per (Czabator, 1962). The germination index (G.I.) was calculated as described in the Association of Official Seed Analysts (AOSA, 1983). Seedling vigour index was calculated by multiplying seedling length (root length + shoot length) with the corresponding germination percentage and the values were recorded and Seedling Moisture Content (%) basing on oven dry weight was calculated by the formula

$$\text{Seedling moisture content (\%)} = \frac{(\text{Fresh biomass} - \text{Oven dry Biomass})}{\text{Oven dry Biomass}} \times 100$$

....Eq. 2

The recorded observations were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1967) to understand the significance of differences among provenances. Coefficient of variance (CV%) and linear correlation coefficients among studied traits were also calculated. Various genetic parameters like Genotypic Coefficient of Variance (GCV), Phenotypic Coefficient of Variance (PCV), Broad Sense Heritability and Genetic gain were also determined by using the software "Agrigene".

## RESULTS

The present study indicated that the fruit length (2.21cm - 3.87cm), fruit width (2.23cm-3.12cm), 100 fruit weight of fruits (517.50gm-1340.17gm), 100 seed weight (178.53gm - 469.05gm), 100 kernel weight (38.38gm - 99.43gm) and the oil content (27.42%-41.53%) of seeds of *Terminalia bellirica* varied within provenances. Maximum fruits length (3.87cm) and 100 fruit weight (1340.17gm), 100 seed weight (469.05gm) and 100 kernel weight (99.43gm) were observed in case of seeds from Kantamal, Maximum fruits width

(3.12cm) in Deogan and oil content by kernel wt. basis (41.53%) was observed in case of seeds from Kasturi Bahal. However, fruits from Kantamal (3.09 cm) showed at par with the maximum value in seed width and Deogan (41.14%) showed at par with maximum oil content (Table 2). The magnitude of variation (Table 3) observed in different seed characters was found higher in 100 seed weight (61.93%) followed by 100 kernel weight (61.39%).

The study showed the extent of variability present in the seedling characters (Table-4). The analysis of variance showed that there was significant variation ( $p < 0.05$ ) in all the seedling characters among other Candidate Plus Trees. The maximum range of variation was observed in case of vigour index of the nursery sown seedling (2047.98-4313.03) followed by seedling moisture content (175.35-228.63); however, the minimum range of variation (1.15-2.01) was observed in case of germination index (Table 5).

The magnitude of variation observed in different seedling characters were found higher in Germination value (66.84%) followed by Vigour index (52.51%), Peak value (47.70%), Fresh biomass (45.12%), Germination Index (42.78%), Mean daily Germination (36.47%), Germination percent (36.26%), Nursery seedling length (30.95%) and seedling moisture content (23.30%) (Table-5). The extent of variability was also accessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation. Most of the seedling traits germination percentage mean daily germination, peak value, germination value, seedling length, vigour index, fresh biomass and seedling moisture content showed higher values of phenotypic variation and phenotypic coefficient of variation than Genotypic variation and Genotypic coefficient of variation. Higher phenotypic coefficient of variation was recorded in germination value (PCV-36.07%) followed by vigour index (PCV-25.89%), and the lowest was found in moisture content (PCV-5.63%) (Table-6). The heritability was found very high for all the seedling traits. Maxi-

**Table 2.** Variation for seed characters in various provenances of *T. bellirica*.

Provenances	Fruit length (cm)	Fruit width (cm)	100 Fruit weight (gm)	100 Seed weight (gm)	100 Kernel weight (gm)	Oil content (%)
Deogan	3.70	3.12	903.13	325.12	71.52	41.14
Bolangir	3.82	2.96	936.24	327.68	68.81	36.37
Kasturi Bahal	2.83	2.24	517.50	178.53	38.38	41.53
Natada	2.21	2.30	542.07	195.4	43.18	39.56
Kantamal	3.87	3.09	1340.17	469.05	99.43	35.82
Jeypore	2.88	2.23	560.78	201.88	44.41	27.42
Gunupur	2.38	2.28	551.12	187.34	41.21	32.09
Kuchinda	2.24	2.24	597.17	209.23	45.40	33.67

**Table 3.** Analysis of variance and magnitude of variation of seed characters of *T. bellirica*.

Seed Characters	F-Value	Mean	Range	SED	CD (5%)	Magnitude of Variation (%)
Fruit Length	709.016	3.02	2.21-3.87	0.036	0.067	42.89
Fruit Width	548.133	2.61	2.23-3.120	0.025	0.054	28.52
Fruit weight	153.255	731.42	517.5-1340.17	15.809	33.515	61.38
100 Seed weight	137.22	257.22	178.53-469.05	4.83	9.81	61.93
100 Kernel weight	143.76	55.88	38.38-99.43	1.02	2.23	61.39
Oil content	0.832	36.13	27.42-41.53	0.438	0.928	33.97

imum heritability was observed in germination (99.9%), Seedling length (99.9%), Vigour index (99.9%), Oven dry biomass (99.9%) and Seedling moisture content (99.9%)(Table-6). The genetic gain was found higher in seedling traits like Germination value, Vigour index, Peak value, Oven dry biomass and Fresh biomass. The lower genetic gain was recorded in other seedling traits like moisture content. The genetic gain was found highest in germination value (71.97%) followed by Vigour index (53.30%), and the lowest was found in moisture content (15.44%) (Table-6).

Correlation between most of the morphological traits of seed and germination and morphological traits of seedling of progeny test was found positive. Oil content did not show significant correlation with any of the seed, germination and seedling morphological characters. Fruit weight showed positive correlation in case of seed characters with seed weight (0.94) , Kernel weight (0.81) , Fruit length (0.80) and Fruit width (0.76) and germination characters like germination percentage (0.907) , mean daily germination (0.899), peak value (0.781), germination value (0.8910, germination index (0.872) ,seedling length (0.596), vigour index (0.884) and seedling dry weight (0.765) except seedling moisture content . Similarly, Seed weight showed positive correlation with kernel weight (0.895), germination characters with like germination percentage (0.934) , mean daily germination (0.911), peak value (0.812), germination value (0.923), germination index (0.895) and seedling characters with seedling length (0.531), vigour index (0.942) and seedling dry weight (0.653) (Table 7).

## DISCUSSION

Variation refers to the observable difference in individuals for a particular seed character. In the present investigation mean fruit length was found (3.02±0.03cm), fruit width (2.61±0.02cm), 100 fruit weight (731.42±15.80gm), 100 seed weight (257.84±4.83gm) , 100 kernel weight (55.88±2.23gm) and oil content (36.13±0.43%) in all seeds with signifi-

cant difference (p<0.05). Besides, the ranges of variations of each fruit character in all the 9 provenances also revealed significant differences (Table 3). These variations may be due to the fact that this species grows over a wide range of climate as well as edaphic conditions in different provenances (Table 1). Though very little information is available on seed variability study from different provenances in *T. bellirica*. Similar type of studies on seed morphological variation from different provenances were reported by Nayak *et al.* (2020) in *Mahuca latifolia* of Odisha, Abraham *et al.* (2010) in case of *M. longifolia* of Tamil Nadu and Podducherry , Police *et al.* (2013) and Vasanth Reddy *et al.* (2007) in *Pongamia pinnata* of Karnataka and Gairola *et al.* (2011) in *Jatropha curcas* of Uttarakhand. The magnitude of variation ranged from high to moderate in all seed traits with a maximum in seed weight (61.93%) followed by kernel weight (61.39%), fruit weight (61.38%), fruit length (42.89%), oil content in the kernel (33.97%) and seed width (28.52%) (Table 3). This indicated that variations in seed characteristics of *T. bellirica* (Gaertn.) Roxb. occurred in this distribution range and the higher value characters may be taken up for the improvement of the species. Variability in seed traits and oil content of 24 accessions of *J. curcas* collected from different agroclimatic zones of Haryana were assessed by Kaushik *et al.* (2007) and significant differences (P<0.05) in seed size, 100-seed weight and oil content between accessions were reported. Similarly, Gingwal *et al.* (2005) also reported that variability also exists in *J. curcas* with respect to seed morphology.

The maximum Germination percentage (73.32%) was recorded in Kantamal provenance (Table 4) which may be due to its maximum seed weight and the environmental condition of nursey under which seedling is raised. This is in line with the study made by Dwivedi (1993) in *Azadirachta indica* and Devagiri *et al.* (1998) in *Dalbergia sissoo*. They found that the variation observed in the seed characters may be attributed to adverse environmental and differences in their distri-

**Table 4.** Variation of germination and seedling characters of *T. bellirica* in various provenances.

Prove-nance	Germination Percentage (%)	Mean Daily Germination	Peak Value	Germination Value	Germination Index	Vigour Index	Germination Index	Seedling Height (cm)	Fresh seedling biomass (gm)	Dry seedling biomass (gm)	Moisture Content (%)
Deogan	60.19	2.00	3.76	7.53	1.34	2759.48	1.34	45.83	10.90	3.32	228.63
Bolangir	66.56	2.21	4.44	9.17	1.70	3539.18	1.70	53.16	13.43	4.35	207.36
Kasturi Bahal	53.51	1.77	3.82	6.79	1.32	2687.42	1.32	50.21	10.81	3.75	190.4
Natada	50.00	1.59	3.85	5.98	1.33	2741.53	1.33	54.82	11.65	3.92	197.4
Kantamal	73.32	2.44	5.24	12.79	2.01	4313.03	2.01	58.82	15.59	5.46	190.9
Jeypore	55.86	1.88	3.53	6.63	1.36	2327.25	1.36	41.16	11.62	3.73	210.91
Gunupur	50.41	1.67	3.36	5.63	1.25	2047.98	1.25	40.61	9.37	3.07	206.5
Kuchinda	46.62	1.55	2.74	4.24	1.15	2144.7	1.15	45.99	8.72	2.93	202.72
Deogan	51.44	1.77	3.03	5.35	1.48	2502.98	1.48	48.81	9.40	3.52	175.35

**Table 5.** Analysis of Variance and magnitude of variation of seedling characters of *T. bellirica*.

Seedling Characters	Genotype MSS	F-Value	Mean	Range	SED	CD (5%)	CV (%)	Magnitude of Variation (%)
Germination Percentage	228.33	794.69	56.44	46.62-73.32	0.438	0.928	0.95	36.26
Mean Daily Germination	0.26	143.57	1.87	1.55-2.21	0.035	0.074	2.27	36.47
Peak Value	1.67	371.98	3.75	2.74-5.24	0.055	0.116	1.79	47.70
Germination Value	19.41	93.167	7.12	4.24-12.79	0.373	0.790	6.41	66.84
Germination Index	0.21	7517.59	1.44	1.15-1.70	0.004	0.009	0.50	30.95
Vigour Index	1559235.37	4186.72	2784.84	2047.98-4313.03	15.75	33.404	0.69	52.51
Seedling Height	112.361	1839.30	48.82	40.61-58.82	0.202	0.428	0.37	42.78.
Fresh Seedling Biomass	15.06	1238.58	11.31	8.72-15.89	0.090	0.191	0.97	45.12
Dry Seedling Biomass	1.75	12219.62	3.78	2.93-5.46	0.010	0.021	0.31	46.33
Moisture content	682.66	29139.71	201.130	175.35-228.630	0.125	0.265	0.09	23.30

bution range. This, in turn, affects the germination of seeds. Weis (1982) reported that larger sized seeds frequently have greater germination percentage than smaller sized seeds. In the present study, the maximum value of Mean daily germination (2.44) was also observed in Kantamal provenance as germination percentage in Kantamal provenance was highest and days taken for the standard germination test was 30 days for all germplasms. The maximum Peak value (5.24) was recorded in the Kantamal provenance as the number of days required to achieve the peak germination was less although the germination percentage remained nearly the same as Kantamal provenance. Similarly, the maximum Germination value (12.79) was also found in Kantamal provenance, which may be due to high peak value and mean daily germination. Germination index was also recorded maximum (2.01) in Kantamal provenance which may be due to genetical makeup of the seed source and its interaction with microenvironmental factors within nurseries like soil temperature, atmospheric temperature, relative humidity and water holding capacity of nursery soil mixture which affects the daily rate of germination. Maximum seedling height (58.83cm) was observed in Kantamal provenance which may be due to maximum seed weight of Kantamal provenance that provides more food production of healthy seedling in the earlier stages promoting better seedlings (5.46gm). The maximum Vigour index (4313.03) was found in Kantamal provenance, which may be due to high values of germination percentage and seedling length. The maximum Fresh weight of seedlings (15.89gm) and oven-dry weight (5.46gm) was record-

ed in Kantamal provenance (Table-4) which may be because of better growth of seedlings. The finding was also inline as reported by Saverimuttu and Westoby (1996) that the seedling from a larger sized seed may have sufficient reserves to continue growth for a much longer period. Zimmerman and Weis (1983) also reported that seed size affects seedling biomass. In the present investigation, observable differences within seedling characters were observed for all seedling characters recorded the mean value of Germination percentage was found (56.44±0.43), mean daily germination (1.87±0.03), Peak value (3.75±0.05), germination value (7.12±0.37), germination index (1.150±0.004), seedling height (48.82±0.20), vigour index (2784.84±15.75), fresh seedling biomass (11.31±0.09), oven-dry seedling biomass (3.78±0.01) and seedling moisture content (201.13±0.12) in all seeds with a significant difference. Besides that, the ranges of variation and the magnitude of variation of each germination and seedling character in all the 9 provenances also revealed significant differences (Table 5) which indicate that variations in germination and seedling characters occurs and has good scope for improvement. The extent of variability is also assessed by genotypic and phenotypic variances and genotypic and phenotypic coefficient of variation (Subramaniam et al., 1995). All the germination parameters i.e. germination percentage, mean daily germination, peak value, germination value, germination index, vigour index and morphological and biomass parameters studied like seedling height, fresh biomass of seedling, oven-dry biomass of seedling and moisture content of seedling of variation showed high-

**Table 6.** Phenotypic and Genotypic analysis of seedling characters of *T. bellirica* (Gaertn.) Roxb.

Seedling Characters	GV	PV	EV	GCV (%)	PCV (%)	ECV (%)	Heritability (%)	Genetic gain (%)
Germination Percentage	76.01	76.30	0.287	15.44	15.47	0.94	99.6	31.75
Mean Daily Germination	0.08	0.08	0.002	15.66	15.83	2.27	97.9	31.93
Peak Value	0.55	0.56	0.005	19.86	19.94	1.78	99.2	40.75
Germination Value	6.40	6.61	7.208	35.50	36.07	6.40	96.8	71.97
Germination Index	0.06	0.07	0.01	18.36	18.36	0.36	99.9	37.82
Vigour Index	519620.96	519993.40	372.424	25.88	25.89	0.69	99.9	53.30
Seedling Height	37.43	37.49	0.061	12.53	12.54	0.50	99.8	25.79
Fresh Biomass	5.01	5.03	0.012	19.79	19.82	0.97	99.7	40.73
Oven Dry Biomass	0.62	0.58	0.02	20.18	20.19	0.31	99.9	41.58
Moisture Content	227.54	227.57	0.023	7.50	7.50	0.07	99.9	15.44

Table 7. Correlation between morphometric characters of seed, germination and seedling characters of *Terminalia bellirica*(Gaertn.)Roxb.

	Oil content	fruit weight	fruit length	fruit width	Seed weight	Kernel weight	Germn. %	Germn.	Mean daily germn.	Peak value	Germn. value	Germn. index	Seed-ling length	Vigour index	Fresh wt.	Dry wt.	Moisture content
Oil content	1.000	0.067	0.160	0.219	0.021	0.013	0.066	0.045	0.008	0.008	0.003	0.034	0.291	0.168	-0.174	0.079	-0.056
fruit weight		1.000	0.805**	0.763**	0.941**	0.813**	0.907**	0.899**	0.781**	0.891**	0.872**	0.884**	0.596**	0.884**	0.136	0.765**	0.070
fruit length			1.000	0.886**	0.798**	0.657**	0.880**	0.904**	0.617**	0.749**	0.778**	0.752**	0.409*	0.752**	0.313	0.619**	0.110
fruit width				1.000	0.873**	0.515**	0.693**	0.718**	0.436*	0.577**	0.686**	0.647**	0.443*	0.647**	-0.017	0.468*	-0.010
Seed weight					1.000	0.895**	0.934**	0.911**	0.812**	0.923**	0.895**	0.942**	0.531**	0.942**	0.003	0.653**	0.020
Kernel weight						1.000	0.898**	0.865**	0.723**	0.843**	0.813**	0.910**	0.495**	0.910**	0.001	0.548**	0.013
Germn.%							1.000	0.986**	0.857**	0.940**	0.911**	0.920**	0.566**	0.920**	0.440*	0.854**	0.121
Men daily germn.								1.000	0.816**	0.928**	0.906**	0.887**	0.904**	0.887**	0.424*	0.821**	0.092
Peak value									1.000	0.943**	0.840**	0.884**	0.677**	0.884**	0.394*	0.875**	-0.002
Germn. value										1.000	0.910**	0.919**	0.628**	0.919**	0.363	0.890**	0.003
Germn. index											1.000	0.941**	0.712**	0.941**	0.313	0.933**	-0.258
Seedling length												1.000	0.840**	0.840**	0.034	0.805**	-0.423
Vigour index													1.000	1.000	0.287	0.946**	-0.139
Fresh wt.														1.000	1.000	0.428*	0.306
Dry wt.															1.000	1.000	-0.267
Moisture content																	1.000

\*, \*\* indicate correlation estimate significant at 5% and 1% level, respectively

er value for the phenotypic coefficient of variation (Table 6). This indicated that all these traits are greatly influenced by the environment. Higher values for the phenotypic coefficient of variation as compared to genotypic coefficient of variation in germination and nursery growth parameters were also observed by Wani and Wani (2013) during genetic variability study of germination and seedling traits of *Madhuca indica*. The proportion of total variation, which is heritable, is termed as heritability in a broad sense (Lush, 1937). Knowledge of heritability magnitude gives us an idea about the scope of effecting genetic improvement through selection. Johnson *et al.* (1995) observed that high genetic gain is usually more useful than the heritability value alone in predicting the resultant effect from selecting the best individual/seed source and therefore, a heritability estimate alone does not necessarily mean an increased genetic advance. Vigour index, Oven-dry biomass, peak value and Germination value were found very high heritability and genetic gain indicating a wide scope of genetic improvement (Table-6). Similarly, seeds collected from Candidate plus tree have been evaluated for various seed germination and seedling traits following progeny testing in *M. indica* at Uttar Pradesh by Wani and Ahmad (2013), Wani and Wani (2013) and reported to have high heritability and expected genetic gain in germination and nursery growth parameters. Ramachandra (1996) in *Acacia catechu* at Uttarakhand, Devagiri *et al.* (1997) in *Heracleum candicans* at Himachal Pradesh, Srivastava *et al.* (1993) in *Terminalia arjuna* in Jharkhand, Sharma and Sharma (1995) in *Grewia optiva* at Himachal Pradesh and Subramanium *et al.* (1995) in *Eucalyptus grandis* at Tamil Nadu also carried out similar works. On the basis of germination and seedling growth characters, Kantamal provenance can be considered better and may be recommended for further genetic improvement program (Table-4). Kantamal also showed the highest fruit weight seed weight, kernel weight among other seeds collected from various provenances. Although oil content in case of Kantamal was 35.82% which was 15.94% less oil content than the oil content of Kasturi Bahal, however, the oil yield was more in Kantamal provenance as the kernel weight was 159.06% more than Kasturi Bahal (Table-2). However, the seedling seed orchard grown from these raised seedlings of different provenances may be studied in future to confirm the best genotype in terms of oil yield and further improvement programme.

### Conclusion

The present study concluded that significant variations occur among the different provenances of Odisha state in oil content, seed morphological, germination

and seedling characters of *T. bellirica* which can be taken up for further improvement work on the species. Kantamal provenance under Boudh district of Odisha showed higher oil yield among all the provenances which can be presently recommended for collection of seed for oil purpose to meet the biodiesel and other industrial uses.

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