Variability Studies in *Jatropha curcas* L. Germplasm Collected from Different Agro-climatic Zones of India

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Jatropha curcas L. commonly known as 'Ratanjyot' or 'Physic nut' is an important source of biofuel, which has the ability to grow in a wide range of agro-climatic regions. In the present communication, efforts have been made to undertake variability studies in genetic resources of *J. curcas* assembled from seven agro-climatic zones of the country. These zones are considered to be as potential sites for identification of suitable genotypes with desired attributes pertaining to growth and yield parameters as discussed in the present communication.

Key Words: Agro-ecological zones, Intra-zonal variation, *Jatropha curcas*, Provenances, Variability studies

Introduction

Jatropha curcas L. (family Euphorbiaceae) commonly known as 'Ratanjyot' or 'Physic nut' is believed to be a native of Mexico and Central America. It is a drought tolerant large shrub or small tree that occurs throughout the arid and semi-arid tropical regions of the world (Dehgan and Webster, 1979). It has emerged recently as one of the most promising tree borne oilseed species due to its adaptability to a wide range of edaphic and climatic conditions. Of late, energy conservation and its alternative production as biodiesel fuel has gained significant importance in the wake of world energy crisis (Ginwal *et al.,* 2005). *Jatropha curcas* seed oil can be replaced with petroleum based biodiesel fuel which is comparatively more efficient than any other known source of biofuel (Forson, 2004). Thus, a large scale plantation of *J. curcas* genotypes with promising attributes to save the energy, wasteland development, countering greenhouse gas, accumulation and enhancing the income of marginal farmers would be of great importance (Keith, 2000; Gubiz *et al.,* 1999).

Jatropha curcas has adapted and acclimatized itself well in diverse agro-ecological niches in India and simultaneously developed considerable variations. Various geographical and environmental factors (latitude and longitude, elevation, soil moisture, soil nutrients, temperature, type of habitat, site disturbance, etc.) have played important role in creation of variation in seed germination behaviour of *J. curcas*, as also reported by Ginwal *et al.* (2004). Documentation of such variations is necessary to tap the available diversity for utilization in its genetic improvement. Genetic variation in growth and seed traits at the provenance, variety or progeny levels has also been reported in several other multi-purpose tree species such as *Albizia, Acacia* and *Prosopis* (Costa *et al.,* 2005; Wanyancha *et al.,* 1994; El Amin and Luukkanen, 2006; Goel and Behl, 2001). Studies pertaining to genetic variation would help in selection of genetically improved better quality seed for plantation (Burley and Nikles, 1973; Lacaze, 1978). Variations in seed morphology, seedling characteristics, reproductive phenology and yield of *J. curcas* germplasm collected from specific location have also been reported (Ginwal *et al.,* 2005; Rao *et al.,* 2008). Though studies pertaining to different aspects of *J. curcas* have so far been carried out, however variability and adaptability aspects with respect to different agro-climatic zones of India and their interrelationship are still lacking. Thus, it is imperative to determine the variability in germplasm assembled from different provenances in terms of plant growth parameters and morphological traits of seeds mainly to identify the quality germplasm.

The objective of the present study was to observe the morphological variation in seed characteristics and their growth performances in the germplasm collected from different agro-ecological zones of India for exploiting the better adaptability, high seed yield and oil content as well as to understand the interrelationship between seed characteristics and growth phenology.

Material and Methods

A total of 160 accessions of *J. curcas* were collected from seven agro-climatic zones of the country during 2005

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and 2006 (Table 1). The germplasm was collected in the form of cuttings from the identified tree/ shrub having good growth habit, high number of branches and fruit yield during field survey. Rooted cuttings of assembled germplasm along with two genotypes (Chhatrapati and Urlikanchan) as checks were planted in the Experimental Farm, Issapur, NBPGR, New Delhi during 2006-07. The experimental site is located in semi-arid tropical climatic zone which experienced an average temperature between 2°C to 45°C and average rainfall approximately 440 mm during the cropping season. The soil of the site is sandy loam to loamy sandy with 8.0 pH. The experiment was conducted in completely Randomized Block Design and each accession was grown in two rows of 6 m length plot with a row to row spacing of 3m and plant to plant spacing of 2m. A basal dose (5 kg FYM/plant, 50 g urea/plant, 15 g MOP/plant and 60 g SSP/plant) of fertilizer, life saving irrigation and hand weeding operations whenever required were performed. For statistical analysis, 21 representative accessions (IC545440, IC559378, IC565694, IC 566065, IC574433, IC566088, IC559385, IC565695, IC566057, IC565687, IC566080, IC566075, IC566041, IC566044, IC574421, IC574455, IC566040, IC545452, IC566052, IC559381, IC565691), one from each provenance on the basis of their overall performance, were selected.

After establishment, the observations were recorded periodically at different stages of plant growth for each accession using 12 selective descriptors *viz.* plant height (cm), branches/plant, collar diameter, crown cover, fruits/plant, seed length (mm), seed width (mm), seed thickness (mm), 100 seed weight (g), kernel to seed coat ratio, seed yield/plant (g), and oil content (%). For recording seed characteristics, ten randomly selected seeds stored at ambient conditions in medium-term storage (MTS) facility of NBPGR were used for the purpose. Seed length, width and thickness were measured using a digital Vernier Calliper while oil content (per cent) was estimated using Soxhlet method. Seed coat and seed kernel weight were recorded separately to compute seed coat to kernel ratio.

Differences between means were analyzed using unpaired t-test for zones with two provenances only while for other provenances, one-way ANOVA (for all the descriptors) with SPSS 13 statistical software package was used for analysis. Correlation was calculated to determine the interrelationship between seed characteristics and growth phenology parameters.

Results and Discussion

In the present study, intra-zonal variation among seed traits and growth parameters (seed length, seed width

Table 1. Number of accessions collected from provenances of different agro-climatic zones

Zone. No.	Agro-climatic zones	Provenances	Accessions (nos)
1.	Humid western Himalayan region	Uttarakhand	10
		Himachal Pradesh	7
2.	Humid Bengal Assam region	Assam	6
		West Bengal	5
3.	Humid eastern Himalaya region	Arunachal Pradesh	3
		Tripura	3
		Manipur	1
		Meghalaya	1
4.	Sub-humid Sutlej Ganga alluvial plains	Uttar Pradesh	15
		Jharkhand	13
		Bihar	10
		Punjab	3
5.	Sub-humid to humid eastern and south eastern uplands	Madhya Pradesh	10
		Chhattisgarh	10
		Andhra Pradesh	10
		Odisha	7
6.	Arid western plains	Rajasthan	10
		Gujarat	10
		Haryana	7
7.	Humid to semi-arid Western Ghats	Tamil Nadu	10
		Kerala	10

and seed thickness) was recorded maximum for zone 1 followed by zone 4 and zone 3 (Fig.1a, b, c); highest 100-seed weight was recorded for zone 6 and minimum for zone 5 (Fig. 1d); highest kernel/ seed coat ratio was recorded for zone 6 and minimum for zone 7 (Fig. 1e); maximum plant height was recorded for Zone1 and minimum for zone 5 (Fig.1f); highest number of primary branches were recorded for zone 7 and lowest for zone 6 (Fig. 1g); highest oil content was recorded for zone 1 followed by zone 3 and zone 2 (Fig.1h); and highest seed yield was recorded for zone 1 and minimum for zone 7 (Fig.1i). In contrast, maximum fruit yield was recorded for zone 7 and minimum for zone 4 (Fig.1j).

Variability at Provenances Level

Variation in Growth Characteristics

Various growth attributes exhibited considerable variation among them as shown in Table 2. Maximum plant height (375 cm) was recorded for Meghalaya provenance (IC565695), while Chhattisgarh (IC574421) exhibited lowest height (223 cm); maximum number of primary branches (10) was recorded for Kerala provenance (IC574433) and lowest (4.67) for Jharkhand provenance; highest collar diameter (48.67 cm) and crown cover (331.7 cm) were recorded for Tamil Nadu provenance, while lowest collar diameter was recorded for Jharkhand (13.33 cm) and lowest crown cover (149.2 cm) for Andhra Pradesh provenances, respectively.

Variation in Yield Characteristics

Highest seed yield (630 g/plant) was recorded for Assam provenance (IC565694) and closely followed by Tamil Nadu (599.5 g/plant) and Bihar (594 g/plant) while lowest yield (99 g/plant) was recorded for West Bengal provenance. Tamil Nadu provenance (IC559381) showed highest (1974 g /plant) and West Bengal lowest (210 g/ plant) fruit yield.

Variation in Seed Characteristics

While comparing the mean values of different seed characteristics, either significant or insignificant variations were observed among all provenances of different zones. Maximum seed length (18.95 mm) was recorded for Uttarakhand provenance (zone 1) and minimum (15.68 mm) for Odisha (zone 5) (Table 3); maximum seed width was observed for Uttarakhand provenance (11.51 mm) while with the same magnitude also observed for Himachal Pradesh, Assam, Bihar, Andhra Pradesh and Haryana provenances; maximum seed thickness (8.89 cm) was observed for Uttarakhand provenance (zone 1) and minimum (7.56 cm) for Kerala (zone 8); highest 100-seed weight was recorded for Andhra Pradesh provenance (67.32 g) and lowest (42.24 g) for Odisha (both the provenances belong to zone 5); highest kernel/ seed coat ratio was recorded for Haryana provenance; highest oil content (36.2%) was recorded for Uttarakhand provenance followed by Arunachal Pradesh provenance (33.5%), while lowest oil content was recorded for Bihar (28.6%) and West Bengal (28.3%) provenances. Seed viability test indicated that most of the provenances within the zones showed more than 85% viability.

Studies was also conducted for determining the inter-zonal variations for different seed characters. Most of the seed characters showed significant variability among provenances of different zones (Table 3). All zones showed significant variation for seed length (except zone 4), seed width (except zone 4 and zone 6), seed thickness (except zone 1), while 100-seed weight also showed significant variation among provenances within different zones (except zone 1 and zone 6).

Phenotypic Association among Different Traits

The phenotypic correlation among the 12 traits showed interrelationship among all characters (Table 4). The seed length exhibited high significant positive correlation with seed width, seed thickness and 100-seed weight. Both seed width and seed thickness showed high correlation with each other. Seed weight also showed significant correlation with oil per cent. Plant height exhibited significant positive association with collar girth, crown cover, seed yield/plant and fruit yield/plant. Primary branches were significantly correlated with plant height, crown cover and fruit yield/plant. Collar girth also showed positive correlation with crown cover, seed yield/plant and fruit yield/plant. High significant positive correlation between seed yield/plant and fruit yield/plant was also recorded.

Thus, *J. curcas* germplasm collected from different agro-ecological zones in the present study has considerable amount of variation in morphological traits pertaining to seed, growth and yield parameters within the zones as well as among the provenances. Since the germplasm was collected from approximately same age group of trees (as per passport data record) growing in different geographical locations, hence the variation in

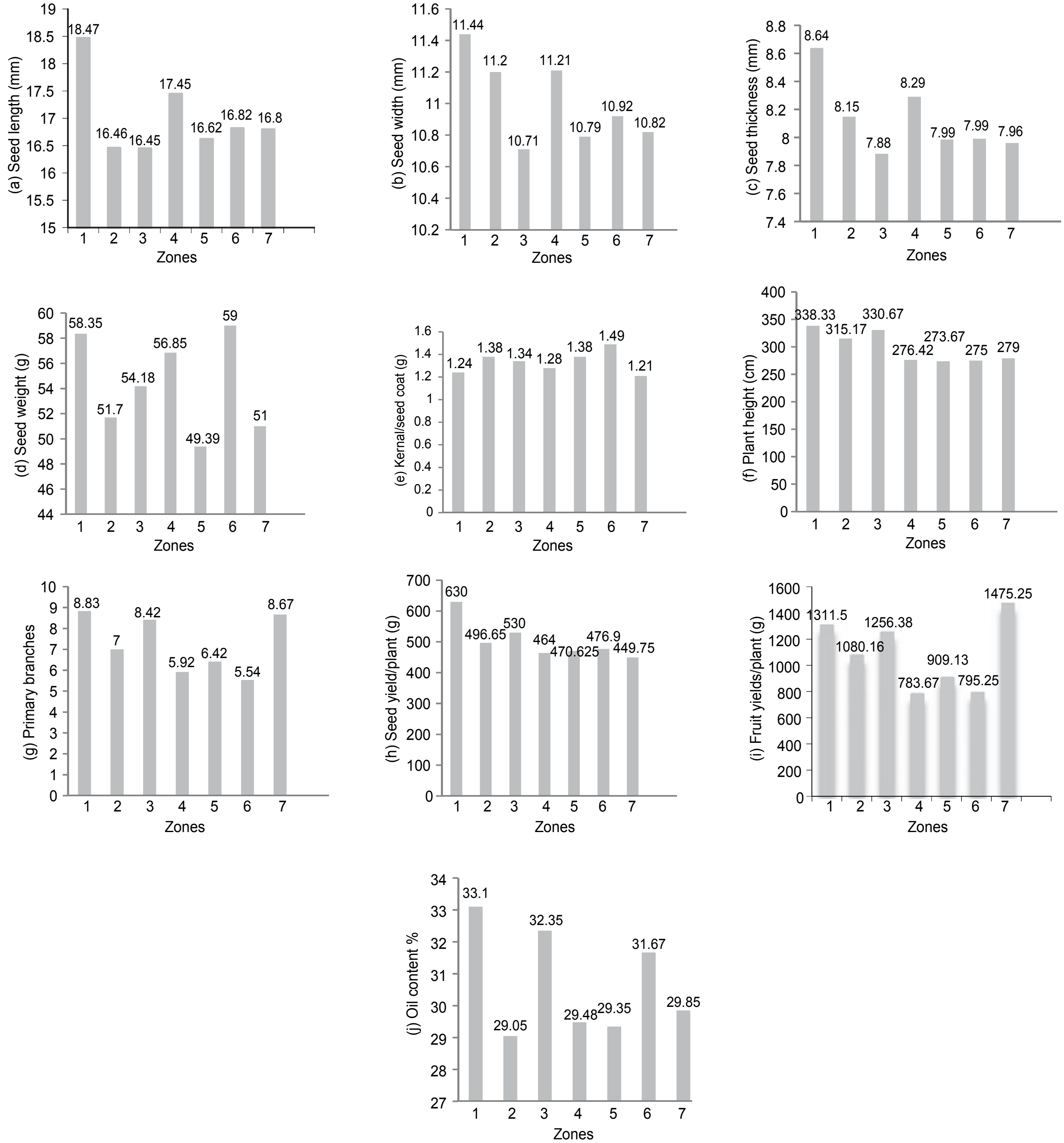

Fig. 1. Zonal variation for (a) seed length , (b) seed width, (c) seed thickness, , (d) seed weight, (e) kernel/seed coat, (f) plant height, (g) primary branches, (h) seed yield/plant, (i) fruit yield/plant, and (j) oil % (Zone 1: Humid western Himalayan region, Zone 2: Humid Bengal Assam Region, Zone 3: Humid eastern Himalaya region, Zone 4: Sub-humid Sutlej Ganga alluvial plains, Zone 5: Sub-humid to humid eastern and south eastern uplands, Zone 6: Arid western plains, Zone 7: Humid to semi-arid western)

morphological parameters is obvious. These variations may be attributed to genetic nature of the *J. curcas* as it is adapted to diverse environmental conditions (Ginwal, 2005). Germplasm assembled from different geographical regions has acclimatized itself with the local climatic conditions (dry semi-arid condition) of Delhi and thus, showed variation accordingly. Such variations have also been reported in *Azadirachta indica* (Kaura *et al.,* 1998), *Acacia nilotica* (Gera *et al.,* 1976), and *A. catechu* (Kumar *et al.,* 2004) when grown in different situations.

Table 2. Provenances variations in plant attributes of *Jatropha curcas* collected from different zones (Mean) in field trial

Agro-climatic zones	Provenances	Plant height (cm)	Primary branches	Collar dia-meter (cm)	Crown cover (cm)	Seed yield/ plant (g)	Fruit yield/ plant (g)
Humid western	Uttarakhand	336.7	8.67	32.33	259.2	540.0	1177.00
Himalayan region	Himachal Pradesh	340.0	9.00	26.33	285.8	453.3	983.00
Humid Bengal	Assam	308.3	7.33	26.00	249.2	630.0	1311.00
Assam region	West Bengal	322.0	6.67	22.33	304.2	99.0	210.00
Humid eastern	Arunachal Pradesh	348.7	9.67	34.67	309.2	574.5	1414.00
Himalaya region	Manipur	320.0	9.00	27.67	274.2	533.0	1261.00
	Tripura	279.0	6.67	28.06	233.3	451.0	912.00
	Meghalaya	375.0	8.33	30.33	327.5	561.5	1438.00
Sub-humid Sutlej	Uttar Pradesh	325.0	7.33	40.67	236.7	548.0	1233.00
Ganga alluvial plains	Punjab	270.7	5.67	25.67	228.3	391.0	617.00
	Bihar	263.3	6.00	19.00	234.2	594.0	820.00
	Jharkhand	246.7	4.67	13.33	229.2	323.0	463.00
Sub-humid to humid	Odisha	265.0	7.67	40.00	268.4	410.0	912.00
eastern and south	Madhya Pradesh	318.3	6.67	24.67	206.7	407.5	830.00
eastern uplands	Chhattisgarh	223.0	5.33	19.00	198.3	592.5	1220.00
	Andhra Pradesh	288.3	6.00	22.33	149.2	472.5	674.00
Arid western plains	Haryana	284.0	7.67	27.33	223.3	405.0	927.00
	Rajasthan	253.3	5.67	35.67	297.5	439.0	571.00
	Gujarat	286.7	3.00	27.00	272.5	386.7	888.33
Humid to semi-	Tamil Nadu	324.0	7.33	48.67	331.7	599.5	1974.00
arid Western Ghats	Kerala	234.0	10.00	25.00	278.3	300.0	976.50
LSD		19.5	0.72	3.15	24.7	–	–

In the present study, plants in zone 1 (humid western Himalayan region) showed excellent and stable performance with respect to almost all traits of seed morphology, growth and yield parameters as topographically this zone is characterized with moderate rainfall, temperature and better soil quality; perhaps this might have lead to better growth of plant and seed characters. Plants in zone 6 (arid western plains) showed poorest performance with regard to seed traits because of low rainfall, high temperature and harsh environmental conditions. Plants in zone 3 (humid eastern Himalayan region) also did not show good performance for seed morphology due to high humidity, frost and flood conditions.

Variation in traits pertaining to seed morphology of *J. curcas* among various provenances as observed in the present study have also been reported by Kausik *et al.* (2003) and Ginwal *et al.* (2005) in their studies. Multiple factors may be responsible to induce and maintain variations in seed size. Provenances within, the zones also showed differences in seed size due to location specific variations in climate, soil fertility and topographic conditions. Seed morphological study is important because the performance of seed immediately after germination is governed by the seed size (Willan, 1985). Hence, recording observations on seed size was important because of availability of more food reserve to produce large seedling with better survival chance whereas small seeds may have a selection advantage due to wider and more effective dispersal mechanism. Manga and Sen (1995) have also observed that germination in *Prosopis* can be improved by selecting large and heavy seeds. In our study, plants in Uttarakhand provenance showed heavy and large sized seeds (65.4 g) and highest oil content (36.2%). During field survey to Uttarakhand, it was observed that the vegetative growth was high as compared to seed yield, may be due to low temperature and short day length. But when the same germplasm was grown in Delhi condition (having high temperature and long day length), the seed yield, oil content and fruit yield were recorded high. Armstrong and Westoby (1943) and Uniyal *et al.* (2002) reported that seed size and seed weight are considered important parameters for improving seedling productivity and reducing nursery cost through selection of quality seeds. Wide variation in seed oil content was reported in various tree-borne oilseed species (Johansson *et al.,* 1997; O'Neil *et al.,* 2003; Vollmann *et al.,* 2007 and Rao *et al.,* 2008). A significant variation in range of oil content (28.3-36.2%) of *J. curcas* seed obtained from different habitats in present study provides a viable selection alternative to use in improvement programmes.

Table 3. Provenances variation in seed characters of *Jatropha curcas* collected from different zones (Mean)

Agro-climatic zones	Provenances	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100-seed weight (g)	Germination (%)	Oil (%)	Kernel/ seed coat
Humid Western	Uttarakhand	18.95	11.51	8.89	65.4	9.67	36.2	1.17
Himalayan region	Himachal Pradesh	17.99	11.38	8.39	51.3	9.00	30.0	1.30
t-value		3.12	7.01	NS	NS	NS	–	–
Humid Bengal Assam	Assam	17.84	11.38	8.29	58.90	9.33	29.8	1.35
region	West Bengal	16.46	11.03	8.01	44.50	10.00	28.3	1.39
t-value		5.52	3.25	2.29	9.71	2.00	–	–
Humid Eastern Himalayan	Meghalaya	16.93	10.82	7.90	56.26	10.00	31.5	1.47
region	Tripura	15.79	10.38	7.75	50.38	8.67	32.2	1.31
	Arunachal Pradesh	16.84	11.11	8.08	64.68	10.00	33.5	1.31
	Manipur	16.25	10.53	7.80	45.40	8.67	32.2	1.27
LSD		1.04	0.53	NS	4.56	1.05	–	–
Sub-humid Sutlej Ganga	Punjab	17.33	11.17	8.27	57.50	9.67	28.7	1.42
alluvial plains	Uttar Pradesh	17.61	11.20	8.40	53.00	9.33	30.6	1.13
	Bihar	17.43	11.38	8.49	59.62	10.00	28.6	1.22
	Jharkhand	17.43	11.08	8.01	57.28	9.67	30.0	1.35
LSD		NS	NS	0.49	3.04	NS	–	–
Sub humid to humid eastern and	Madhya Pradesh	16.87	11.00	7.99	44.09	8.67	28.8	1.28
south eastern uplands	Andhra Pradesh	17.20	11.29	8.37	67.32	9.67	31.2	1.40
	Chhattisgarh	16.74	10.70	7.98	43.90	9.33	30.1	1.30
	Odisha	15.68	10.38	8.29	42.24	9.67	29.3	1.20
LSD		1.02	0.54	0.51	1.37	NS	–	–
Arid western plains	Haryana	16.64	11.29	8.13	57.73	8.33	31.8	1.80
	Rajasthan	16.65	10.55	7.86	61.28	10.00	32.4	1.43
	Gujarat	17.16	10.92	7.99	57.60	10.00	30.8	1.22
LSD		1.25	NS	0.72	NS	NS	–	–
Humid to semi-arid	Tamil Nadu	17.37	11.12	8.37	57.69	10.00	29.1	1.29
Western Ghats	Kerala	16.22	10.52	7.56	45.13	10.00	30.6	1.14
t-value		5.21	2.68	9.36	6.97	–	–	–
Pooled LSD		0.39	0.24	0.22	1.64	0.38	–	–

Literature indicates that plant attributes of *J. curcas* have exhibited considerable amount of variations in different progeny trials (Ginwal *et al.,* 2005). Similarly in our experimental trial, the growth parameters of germplasm from Arunachal Pradesh provenances have shown good performance while seed yield traits of Tamil Nadu provenances showed better performance as compared to others. Plant height and number of branches are considered important characters (as major selection indices) when the objective is to select *J. curcas* for agro-forestry system while high yield is one of the important traits to utilize in crop improvement programmes (Rao *et al.,* 2008). The purpose of provenances testing under the present study was mainly to understand the variation pattern as well as to aid in selection of well-adapted and highly productive seed source for silvicultural practices.

Correlation coefficient has revealed interesting inter-relationship in both seed characters and growth parameters studied. Significant correlation of seed weight was there with oil content, seed width and seed thickness; hence seed weight and seed size can be considered most important traits for selection of early types from a seed lot of any seed source. Similar findings have also been reported by Rao *et al.* (2008) and Kausik *et al.* (2007).

Significant correlation of plant height with number of branches, collar girth, crown cover, seed yield and fruit yield also indicates that selection from early plantation can be made on the basis of such parameters. This is further supported by significant association of primary branches with fruit yield and seed yield. The correlation between these parameters can be explained by the fact that during the phenological succession of appearance of physiological and morphological determinants of yield, the number of branches contributed to higher number of flowers which in turn to higher yield. Similar results have also been reported in other crops as well (Bhargava *et al.,* 2007; van Osteroma *et al.,* 2006). In case of *J. curcas*, selection of plant types not only depend upon seed yield but also depend on the morphological and

Table 4. Phenotypic correlation among different seed characters and plant attributes

Trait	Seed length	Seed width	Seed thickness	Seed weight	Kernel/ seed coat	Oil%	Branches	Height	Collar girth	Crown cover	Seed yield/plant	Fruit yield/plant
Seed length		0.845**	0.897**	0.586**	-0.35	0.209	-0.04	0.169	0.11	0.055	0.228	0.144
Seed width			0.895**	0.644**	-0.32	0.037	-0.17	0.079	0.13	0.091	0.024	-0.10
Seed thickness				0.64**	-0.36	0.2	-0.07	0.223	0.189	0.038	0.172	0.106
Seed wt.					-0.03	0.459*	-0.14	0.128	0.147	-0.03	0.363	0.111
Kernel/ seed coat						-0.11	0.064	0.107	0.112	-0.2	-0.04	-0.13
Oil %							0.241	0.205	0.067	0.09	0.338	0.166
Branches								0.468*	0.341	0.394*	0.11	0.43
Height									0.395*	0.458*	0.401*	0.392
Collar girth										0.525*	0.417*	0.585**
Crown cover											0.093	0.32
Seed yield/plant												0.777**

* Significance at 5% level.
** Significance at 1% level.

growth parameters because yield trait stabilized only when plant attained 4-5 years of growth cycle (Barua, 2011). This plant did not express any interrelationship between seed phenology and growth parameters perhaps because the growth of plant is regulated by availability of nutrients, water and other biotic factors and seed size depends upon the food storage capacity of seed.

The overall findings from the present study revealed that the considerable genetic variability exists among the germplasm assembled from provenances of different agro-ecological zones. The significant zonal difference indicates that various environmental factors also play a major role in creation of variability and adaptation of *J. curcas* to a wide range of climatic conditions. This experimental study also indicates that for selecting good genotypes, some important characteristics such as large and heavy seeds, high oil content, good plant height and branching pattern with high seed yield may be important traits for genetic improvement of *J. curcas*. In the present study, zone 1 (humid western Himalayan region) showed high value for number of branches, seed yield, 100-seed weight and oil content followed by zone 6 (arid western plain) and zone 3 (humid eastern Himalayan region). Therefore, selecting best genotypes from above mentioned zones will improve agro-forestry system and energy plantation in the wastelands, besides boosting the economic status of farming communities with marginal holdings.

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