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Identification of areas of diversity and distribution of *Pongamia* based on altitude and seed traits

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ABSTRACT

A total of 123 germplasm accessions of *Pongamia pinnata* were collected from peninsular India. Majority, i e 64 accessions (52%) were collected from an altitudinal gradient of 0 to 250 m with oil content ranging from 15.0 to 46.0% and only 0.8% of accessions collected from altitude more than 1 000 m have exhibited modest oil percent of 27.7%. Using DIVA-GIS software, grid maps indicating diversity for oil content and 100- seed weight were generated for these accessions. Highly variant lines for oil content were observed in Prakasam and Srikakulam districts of Andhra Pradesh. However, high diversity index for 100-seed weight was observed in Srikakulam and Chittoor districts of Andhra Pradesh. Rayagad district of Odisha was a potential region for diverse lines of *Pongamia* germplasm for various seed traits including oil content. High regions of diversity within the surveyed districts have been identified. The present study enabled us to find out suitable altitudinal gradient and diversity rich pockets from Peninsular India.

Key words: Germplasm, Distribution, Diversity index, Mapping, *Pongamia pinnata*

Pongamia pinnata L.Pierre, popularly known as *karanj* in is native to India (Allen and Allen 1981) but well naturalized in countries like Sri Lanka, Pakistan, Japan, Fiji, New Zealand, Australia and other south-east Asian countries. It is commonly found along banks of streams and rivers or near sea coast in beach and tidal forests (Anonymous 1965). It can withstand temperatures ranging from slightly below 0 °C to 50°C and comes up in areas with annual rainfall of 500 to 2 500 mm. It grows upto an altitude of 1 200 m (Paul *et al.* 2008). The kernel produces non-edible oil which can be used for soap making, lubricant and medicinal remedies against rheumatism (Burkill 1966), arthritis, whooping cough and skin ailments. Seed cake is an excellent organic fertilizer with 4% N, 1% P_2O_5 and 1% K_2O (Rajeshwar *et al.* 2006). Biodiesel from *Pongamia* has a high cetane number compared to petro-diesel, indicating higher engine performance and it can cater to the needs at rural level for self-sustainability, to supply fuel to automobile sector at an affordable price and also to meet the huge gap between demand and supply of crude oil (Tiwari 2002). The composition of *Pongamia* seed oil includes saponification number (196.7), iodine number (80.9) and cetane number (55.84) which indicate ignition quality of fuel. *Pongamia* is an evergreen, briefly deciduous, glabrous tree with straight or crooked trunk (Mukta and Sreevalli 2008) having grey-brown, smooth or faintly vertical fissured bark. Normal tree can reach height up to 25 m. The flowers are white, pink or purple coloured. Pod shape is elongated with 1–2 seeds / pod, which are either elliptical or reniform in shape. Seeds ripen from January to June and pod production starts after 5–7 years and they do not open naturally. The seed stores well, without having any adverse effect on physiological and biochemical parameters at 4° C and 20° C and 33% RH (Santosh Kumar *et al*. 2011) The seed yield is said to range from 9 to 90 kg /tree (Anonymous 1965). Considering its wide applicability and uses, germplasm collection and assessment of diversity has been attempted by Pandravada *et al.* (2006) from Southern Andhra Pradesh, Kaushik *et al*. (2007) from Haryana and by Sunil *et al*. (2009) from parts of Andhra Pradesh and Odisha. However, ecological requirements, distribution of diversity to identify the suitable ecosystems and regions have not been studied. Hence, assessment of variability along altitudinal gradient and diversity using DIVA–GIS application has been attempted.

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MATERIALS AND METHODS

Regional Station, National Bureau of Plant Genetic Resources, Hyderabad conducted explorations and surveys during 2006–07 and 2007–08, for the systematic collection of *P. pinnata* germplasm from different ecogeographic zones covering forests, mountains, river streams and protected areas of peninsular India. While collecting the germplasm, it was ensured that fruits from all sides of the plant were collected representing uniformity in collection strategy for maintaining true seed character of a particular accession. Passport data was recorded for each accession including geographical coordinates (Garmin 12, GPS) and some phenotypic traits were also documented *in situ*. The altitudinal zones of the collection sites were grouped into five classes (0–250 m; 251–500m; 501–750 m; 751–1 000m; >1 000 m). Oil content was analyzed using Soxhlet method (Alberta and Benjamin 2009). The software DIVA–GIS was used to study the distribution of diversity on geographical scale. The collected germplasm was raised in nursery in 2009 and subsequently transferred to the field gene banks located in Agro forestry Division of Acharya NG Ranga Agricultural University and Central Research Institute for Dryland Agriculture, both located at Hyderabad, India.

RESULTS AND DISCUSSION

A total of 123 accessions of *P. Pinnata* were collected from Vizianagaram (5), Srikakulam (19), East Godavari (1), Chittoor (19), Prakasam (12), Nellore (4), Karimangar (16) and Adilabad (28) districts of Andhra Pradesh and Rayagad (6) and Koraput (13) districts of Odisha of peninsular India. The habitat varied from water streams, tropical dry deciduous forests, tribal hamlets, disturbed and undisturbed rangelands and foothills of Eastern Ghats. The variation in the altitude (0 to 1002 m) of natural plant population and site of collection which formed base for sampling the germplasm of *P. pinnata* is depicted in Fig. 1. There was a significant decrease in the number of accessions collected from low altitude (0 m) to higher altitude (1 000 m) as 64 accessions (> 50%) were collected from low altitudinal range (0–250 m), whereas only one accession was collected from high altitude (>1 000 m) that accounted for less than 1% (Table 1). The distribution of *Pongamia* along varying altitudinal gradient is governed by various interacting factors such as biological, climatic and historic. The high oil content and distribution of more accessions at mid altitude may be due to optimum humidity, high productivity and optimal resource availability. The low frequency and distribution of *Pongamia* at higher altitude may be attributed to eco-physiological constraints such as reduced growing season, low temperature and low eco–system productivity at high altitudes.

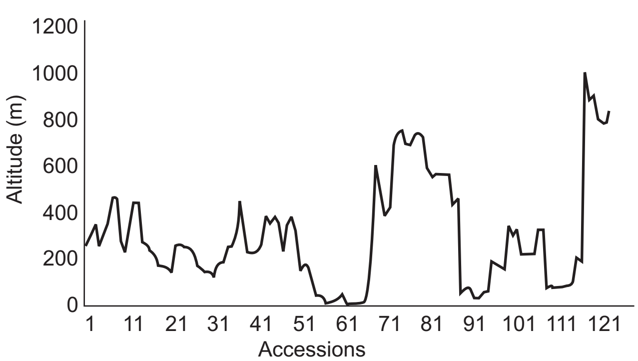

Fig 1. Variation in altitudinal range of *Pongamia* germplasm

Table 1 Frequency distribution of *Pongamia* germplasm along altitudinal gradient based on oil content and100-seed weight

Altitude (m)	No. of accessions	Oil (%)		100-seed weight (g)	
		Range	Mean	Range	Mean
0–250	64	15.00 – 46.00	34.03	58.00 – 273.20	132.30
251–500	31	25.06 – 47.26	36.00	70.00– 247.00	145.01
501–750	15	25.58 – 44.14	33.11	49.00– 145.00	87.40
751–1 000	12	24.77– 39.82	34.11	36.00– 181.00	136.26
>1 000	01	27.68	27.68	78.00	78.00

The frequency distribution of *Pongamia* accessions along the five altitudinal gradients is presented in Table 1. Good variation in mean oil content among various altitudinal gradient was observed. Lower altitudinal regions, 0–250 m, recorded 34.0 % of oil content and higher altitudinal regions, (> 1 000 m), have recorded low mean oil content of 27.7%. The variation in oil content between two extreme altitudinal gradients was 6.3% only. The high mean value for oil content (36%) was peaked at middle altitudinal gradient (251–500 m), which accounts for 25% of total accessions collected while 12% of accessions in the altitudinal range of 500–750 m, have mean oil content of 33.1%. Wide range for oil content (15.0–46.0) was observed between the altitudinal ranges of 0 to 250 m. Accessions IC552406 and IC552411 recorded highest oil content of 47.3 and 47.2 %, respectively, which were collected from an altitude of 351 and 330 m in Adilabad district of Andhra Pradesh. Generally, average oil per cent in *Pongamia* ranges from 30 – 35% (Pandravada *et al.* 2006) but from the present study it may be inferred that an altitudinal range of 251–500 m may be more conducive for recovering high oil content. Fiftytwo per cent (52%) of accessions recorded mean oil content of 34.0% and 0.8 % of accessions exhibited an oil per cent of 27.7 %. Pant *et al.* (2006) reported decrease in oil content of *Jatropha curcas* with an increase in altitude. However, in the present study, *Pongamia* showed an increase in oil content up to 500 m. At higher altitudes (>1 000 m) low oil content was recorded, which may be because at higher altitude dominant utilization of photo assimilation is done for growth as compared to production of oil. For 100–seed weight, diverse lines were observed in the lower altitudinal ranges of 0–500 m (Table 1). Lower altitudes (0–250 m) recorded high range (58.0–273.2g) while mid altitude range (251–500 m) recorded a range of 70–247g with highest mean 100-seed weight of 145.0g. An altitude of 0–500 m may be ideal range for collection of variable germplasm lines for oil content and 100-seed weight in *Pongamia*. High heritability was reported for oil content and 100-seed weight with no correlation between the traits (Sunil *et al.* 2009b*).* The population with more seed weight and even with moderate oil content may give more total oil (ml) as reported by Rajneesh *et al*. (2009) in *J. curcas.* Hence, these two traits, viz oil content and 100-seed weight were used to further study the diversity using DIVA–GIS software.

The results of the diversity analysis of the germplasm lines for oil content using DIVA–GIS (Shanon diversity index) signify variation in the extent of diversity and coefficient of variation. Srikakulam and Vizianagaram in north coastal zone, Karimnagar in Telangana region and Chittoor district in Rayalseema region of Andhra Pradesh and Koraput and southern part of Rayagad district of Odisha have recorded high value of Shannon diversity index (2.4 to 3.0) for oil content. Germplasm collected from Nellore district has less diversity for oil content. High cv % was observed in Prakasam and Srikakulam districts. Such regions having high cv % must be targeted for *in situ* clonal multiplication. Again, Nellore district showed low per cent of co-efficient of variation for oil content. Srikakulam district of Andhra Pradesh appears to be most potential area for rich diversity and highly variant lines. It is located in the north-eastern corner of Andhra Pradesh dominated by tribals with altitude ranging from 400 to 1 700 m, main soil types are red with clay base predominates. Such whole set of eco-geographic conditions might have contributed for its wide spread distribution and diversity.The high diversity of *Pongamia* for 100-seed weight was observed in Srikakulam, Vizianagaram, Rayagad and Koraput district whereas less divergent lines were observed in Nellore district. DIVA–GIS analysis showed that only Chittoor district had germplasm with high cv % (40–51%) for 100-seed weight. Vizianagaram and part of Srikakulam districts and Koraput district of Odisha has less cv % for 100-seed weight as against high diversity for oil content which confirm the report of Sunil *et al.* (2009b) that there is no correlation between seed weight and oil content. Prakasam and Nellore districts exhibited less diversity for most of the traits under study. Thus, identification of such areas helps to formulate the policies and programme to take up afforestation assignment on waste lands. DIVA–GIS has been successfully used in assessing biodiversity and in identifying areas of high diversity in wild potatoes (Hijmans *et al*. 2000), horsegram (Sunil *et al*. 2008) *J. curcas* (Sunil *et al*. 2009a), blackgram (Babu Abraham *et al*. 2010), Canavalia fatty acids (Sivaraj *et al*. 2010), medicinal plants (Varaprasad *et al*. 2007) and agrobiodiversity (Varaprasad *et al*. 2008). Present investigation reveals that highly variant lines for all seed characters, viz seed length, seed width, seed thickness, 100-seed weight and oil content were found in Srikakulam and Vizianagaram districts, which may also be translated into the general diversity of the *P. pinnata* germplasm which may espouse the fact that the Eastern Ghats may be one of the centers of origin as it is believed to be native of India (Paul *et al.* 2008).

Specific regions exhibiting high diversity and distribution within the surveyed districts are presented in Table 2. In Srikakulam district, widespread distribution of *Pongamia* was recorded in forest ecosystem of all surveyed mandals, which have contributed for high diversity and variable lines as natural plant population were observed. The trees in these regions are characterized by tall > 25 m height, girth > 60 cm, dense branch habit and branching pattern ranging from erect to semi-erect and drooping types. Most of the collected accessions in Tekkali mandal had 2 seeds / pod. Leaf galls infestation was observed in Ichchapuram mandal. In Karimnagar, *Pongamia* plant population was widely distributed throughout the district. All the 14 surveyed mandals were found to be potential regions for collection of diverse *Pongamia* population with huge and heavy bearing trees. Accession from Kataram mandal showed purple coloured flowers. The germplasm from Vemulvada and Sultanabad mandal had 5 and 7 leaflets respectively while Huzurabad and Husnabad collections had large pods and kernels. In Koraput (Odisha), Simliguda, Mastiput, Rajput and Nandapur are the important tehsils for natural population of *P. pinnata*. Most of the accessions collected from Koraput had dark green leaves. In Simliguda profuse and erect branching lines were collected. Lamtaput and Nandapur tehsils had huge trees having > 35 ft. height. Moramam tehsil in Rayagad district has dense subtropical forest, which is inhabited by tribals and is also potential area for collection of bold-seeded and sharp beak germplasm. Hilly tract of Palamaneru, Rampicherla, Kotakata, Vayapada, Pileru, Kevipally, Punganuru and Madanapalle is the potential area for exploitation and identification of the elite genotypes and collection of diversity. The trees in this region are tall (> 25 ft height) with wide girth and long trunk. Most of the collected accessions had erect branching pattern. Elite lines of *P. pinnata* from these diversity rich pockets can be domesticated for cultivation under different agro-ecological and production system including agro-forestry programmes on degraded and community waste lands (Kesari and Rangan 2008). Such regions of high diversity and distribution may be harnessed for (i) recollection of diverse lines, (ii) formulate strategies for *in situ* conservation, and (iii) study the interaction between plant ecosystem and anthropogenic factors.

The existence of immense diversity in *Pongamia*, an

Table 2 Areas of high diversity and associated ecosystems/habitat of collected *Pongamia* germplasm

District	Mandal	Ecosystem/Habitat
Srikakulam	Bamini	Forest
	Tekkali	Mountainous
	Patapatnam	Mountainous
	Mellyaputti	Hilly dissected
	Ichchapuram	Disturbed range land
	Kanchili	Disturbed range land
	Rajam	Disturbed range land
	Regidi	Cultivated (field bund)
	Sompet	Sea coast
Chittoor	Kotakata	Forest
	Rampicherla	Forest
	Bakarapet	Mountainous
	Pileru	Mountainous
	Kevipally	Range land
	Palamner	Rangeland
	Srikalahasti	Cultivated (field bund)
	Chandragiri	Cultivated (field bund)
	Bangarapalem	Cultivated (field bund)
	Punganur	Cultivated (field bund)
	Madanpalle	River bank
	Vayapada	River bank
Karimnagar	Chandurti	Forest
	Mahadeopur	Disturbed range land
	Dharmapuri	Disturbed range land
	Jagtial	Disturbed range land
	Peddapally	Disturbed range land
	Sultanabad	Disturbed range land
	Odela	Disturbed range land
	Huzurabad	Disturbed range land
	Koheda	Disturbed range land
	Malavar	Cultivated (field bund)
	Kataram	Cultivated (field bund)
	Korutla	Cultivated (field bund)
	Husnabad	Cultivated (field bund)
	Vemulwada	Field bund
Rayagad	Moramam	Sub-tropical forest
Koraput	Rajput	Forest
	Lamtaput	Forest
	Nandapur	Forest
	Simliguda	Mountainous
	Mastiput	Mountainous

important biodiesel crop which is native of India offers good scope for realization of its potential through selection and crossing programme. Identification of extent of distribution of diversity is the initial step that would enhance its utilization. The diversity areas, which form pools of natural population, may be effectively harnessed before erosion of diversity by various anthropogenic and environmental factors. Identification of climatic requirements and diversity rich areas for *Pongamia* would facilitate in the sustainable utilization of the regions of diversity and mass plantation programmes in ideal climatic zones of rain shadow areas (water-deficit regions).

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