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Full Length Research Paper

An evaluation on the floral phenology, developmental variation in fruit and seed, maturation period in (*Pongamia pinnata)*

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Pongamia pinnata **is a leguminous tree having enormous potential of producing high seed oil that could be as a source of biofuel. The collection of pods with higher seed quality characters is much important for production of elite seedlings at nursery and hence studies related to seed maturation were initiated as matured seed is the basic character of quality seed. To evaluate the steps in obtaining quality seed from the tree, studies were initiated on floral phenology, fruit and seed maturation and on evaluation of fresh fruit colour variation on seed and seedling quality characters. The results revealed that in pungam, the flowers per inflorescence ranged from 28.4 to 44.0, and only 3-4 per cent of the flowers set as pods. But the seed set was obtained with 80 per cent of the pods. The studies on pod maturation revealed that seeds of pods attained physiological maturation at 26 weeks after anthesis and it was accompanied with the change in colour of pods from green to dark brown and the seed from greenish white to dark brown, where the seeds had potential for higher germination (98 per cent). Evaluation on harvest index based on fresh fruits colour (yellow, light brown and dark brown) revealed that the seeds of light brown fruits recorded the higher germination (96 per cent), and seedling quality characters suggesting the collection of light brown fruits for obtaining good quality seed for sowing. The colour of pods also coincided with the colour obtained with maturation of pod studied with tagged flowers.**

Keywords: ***Pongamia pinnata*****, floral phenology, pod maturation, fruit colours, seed and seedling quality characters.**

INTRODUCTION

Pongamia pinnata (L.) Pierre (Leguminoseae, subfamily Papilionoideae) is a medium sized tree commonly called as Karanj or pungam (Sangwan et al., 2010) that generally attains a height of about 10-20 m and a trunk diameter of more than 50 cm (Troup, 1921). *P. pinnata* is widely distributed throughout tropical Asia and the Seychelles Islands, South Eastern Asia, Australia, India and naturally distributed along the sea coasts and river banks in India (Arote and Yeole, 2010). The species thrives in areas with an annual rainfall of 500- 2500 mm, and a temperature range of 1-38°C. It can resist drought and withstand water logging and slight frost (Beniwal, 2011). For the past one decade, oil from pungam seeds has been seen as a potential source for biodiesel. Pungam seeds contain 30-35% oil and its physical and chemical properties are almost similar to the diesel. However, pungam oil could not be used as such and this oil needs preheating due to high viscosity and conradson carbon residue (Shrivastava and Prasad, 2000). The pungam is being cultivated in large number of gardens

and widely distributed in roadsides in India and has the potential for the biological industry (Scott et al., 2007).

It has been observed that reproductive biology is very important to determine the seed and fruit set, conservation, pollination and breeding systems that regulate the genetic structure of populations (Kukade and Tidke, 2013). Pungam has lot of variability in terms of flowering phenology, fruit color, and fruit maturation period between the ecological zones as well as within the ecological zone (Raut et al. 2011, Patil et al., 2011). Thus, the knowledge on variability and its association with pod and seed traits is prerequisite for genetic improvement of the species. Hence, it necessitates seed source testing prior to an intensive breeding work (Sniezko and Stewart, 1989; Zobel and Talbert, 1984).

A clear understanding of phenological behavior on time of anthesis, time and duration of stigma receptivity, fertilization, mode of pollination, seed development is necessary for breeding programmes to obtain better traits (Rout et al., 2009). Collection of quality seed is very important in this crop as this oilseeds crop loses viability at faster rate and are described by researchers as microbiotic. Seed maturation is the environmentally influenced genetic factor is the major factor that spokes on the quality of the seed. In this huge tree, application of duration for collection of matured seed is cumbersome and requires an alternate means for collection of quality seed. The size of fruits and seeds has been considered as an important variable in the reproductive biology of plants (Khan et al., 2002). But colour of fruit has long been considered as an easier technique for production of quality seeds in forestry (Srimathi et al., 2001). In the past, only very little efforts has been taken to study the phenology and seed maturation aspects in pungam. The present study aims to investigate the floral phenology, developmental variation in fruit and seed, maturation period and evaluating the harvest index based on fruit colour in *Pongamia pinnata*.

MATERIAL AND METHODS

Study area

Morphologically superior pungam trees of 20 years old were selected in a plantation at Coimbatore district, Tamil Nadu, India which is situated at11°1'6 N 76° 58'21 E and 320 MSL. The selected trees were used for studying flower phenology, pod development, seed and seedling quality characters. The laboratory experiments were conducted at the Department of Seed Science And Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Studies on floral phenology

Five different trees were selected from the plantation and ten inflorescences from each tree were tagged at the initiation of flowering and were observed up to pod maturation. During maturation the data on number of flowers per inflorescence, pod per inflorescence, and number of seeds per inflorescence were observed twice a day at morning and evening for the period of 30 days and observations were pooled as weekly intervals. In addition to that, pod setting percentage, seed setting percentage and pod to seed setting percentage were also calculated adopting the following formulae:

$$\text{Pod setting percentage} = \frac{\text{Number of pods formed}}{\text{Total number of flowers per inflorescence}} \times 100$$

$$\text{Seed setting percentage} = \frac{\text{Number of seeds formed}}{\text{Total number of flowers per inflorescence}} \times 100$$

$$\text{Pod to seed set percentage} = \frac{\text{Number of seeds in number of pods}}{\text{Total number of pods per inflorescence}} \times 100$$

Studies on fruit and seed maturation

At peak flowering phase more numbers of matured flower buds (will open on next day) were tagged and observed at weekly intervals for pod colours, pod length (cm), pod breadth (cm), pod weight (g), and seed colours upto 27 weeks . The seeds were also germinated to evaluate the germination potential of the seed.

Evaluation of harvest index based on fruit colour

At the time of maturation, from the whole plantation the fresh fruits (pods) were categorized based on the colour as yellow, light brown and dark brown. Each of the colour grades were observed for fruit length (cm) fruit breadth (cm), fruit moisture content (%) and seed moisture content (%). Fifty fresh fruits (pods) from each colour category were replicated seven times and measured for seed length (cm), seed breadth (cm) (AOAC, 1960). In addition the seeds were also evaluated for the seedling quality characters viz., 100 seed weight (g), germination (%) (ISTA, 1999), root length (cm), shoot length (cm), fresh and dry weight of 10 seedling-1 (g). Based on the values obtained on seed and seedling quality characters three types of vigour index values were computed for each of the colour categories of fruits by using the following formulae (Abdul – Baki and Anderson, 1973).

Vigour index^{1} = Germination (%) x Total seedling length (cm)

Vigour index^{2} = Germination (%) x Root length (cm)

Vigour index^{3} = Germination (%) x Dry matter production 10 seedling^{-1} (g)

Table 1. Flowering phenology and fruit set in *Pongamia pinnata.*

Individual tree	Number of flowers in inflorescence	pod per inflorescence	Number of seeds per inflorescence	Pod set percentage (Flower to pod)	Seed set percentage (Flower to seed)	Pod to seed percentage
T1	40.5	1.6	1.4	4.0	3.5	87.0
T2	29.0	0.6	0.5	2.0	1.7	88.9
T3	44.0	2.1	1.6	4.8	3.6	74.1
T4	28.4	0.5	0.4	1.8	1.3	73.3
T5	36.3	0.9	0.7	2.6	1.9	74.7
Mean	35.7	1.1	0.9	3.0	2.4	79.6
CD (P=0.05)	2.9	0.3	0.4	0.9	1.0	NS

NS-Non significant

Statistical analysis

Data were statistically scrutinized as per Panse and Sukhathme (1985) and F test was used to understand the level of significance (5%). Since all the experiments were laboratory basis, the experimental design adopted was completely randomized design. The percentage values were transformed to arcsine values before analysis.

RESULTS AND DISCUSSION

Flowering phenology

It was observed that *Pongamia pinnata* initiated flower buds from mid-April to mid of May. The data (Table 1) showed that on an average of 35.7 flowers were observed per inflorescence, which had the range varying from 28.4 to 44 flowers. The pod and seed set percentage obtained was only 3.0 and 2.4 per cent respectively. However, 80 per cent of the pods set seed. Formation of flowers, pod or seed setting characters are highly variable in pungam trees from locality to locality, the variation may be related with genetic effect of the tree (Nelsonnavamaniraj, 2005) and the environmental factors prevailing at the particular locality (Dhillon et al., 2009). Similar variation in seed setting and percentage was also reported in different crops by different researchers (Gassama-Dia et al., 2003, Ndoye et al., 2004, Natarajan and Srimathi, 2008, Bentos et al., 2008, Piechowski and Gottsberger, 2009, Adjaloo et al., 2012 and Kukade and Tidke, 2013).

Studies on fruit and seed maturation

Daily observations on flowers revealed that the flowers ended with the fruit bud formation from 19 to 25 days after anthesis (end of May). The pod colour was light green from first week and at fifteenth week the colour changed to dark green from 16th week to 20th week, while the colour was greenish brown in 21st and 22nd week, which changed to yellowish brown in 23rd and 24th week and finally changed to light brown in 25th and 26th week after anthesis (Figure 1). The seed colour also changed from yellowish white to light brown with advances in maturation. The seeds were able to germinate from 16th week after anthesis (Table 2) and the completion of the seed and pod development took almost 189 to 220 days after anthesis, i.e. 27 weeks after anthesis. In contrast, other study from north India stated that *Pongamia pinnata* needs 327-344 days after the anthesis (Dhillon et al., 2009) indicating that there will be great genetic variation in duration of seed and pod maturation, seed size, pod colours and other morphological features and these characters are strongly depends the species, those occurs in a particular ecological and climatic regions (Divakara et al., 2010, Patil et al., 2011).

Seeds of pungam changed their colour from greenish white to brown from first week of bud initiation to 26th week of maturity. The *Pongamia pinnata* fruit and seed quality characters revealed that the growth measurements increased with changes in fruit colours from light green to light brown and then it decreased on changes of fruit colours to dark brown when it was dropped from the tree due to formation of abscission layer . On 26th week the pod size recorded as pod length (5.2cm), pod breadth (3.1cm) and pod weight (6.4cm) were the maximum, concluding that 26 weeks after anthesis is the correct maturity stage

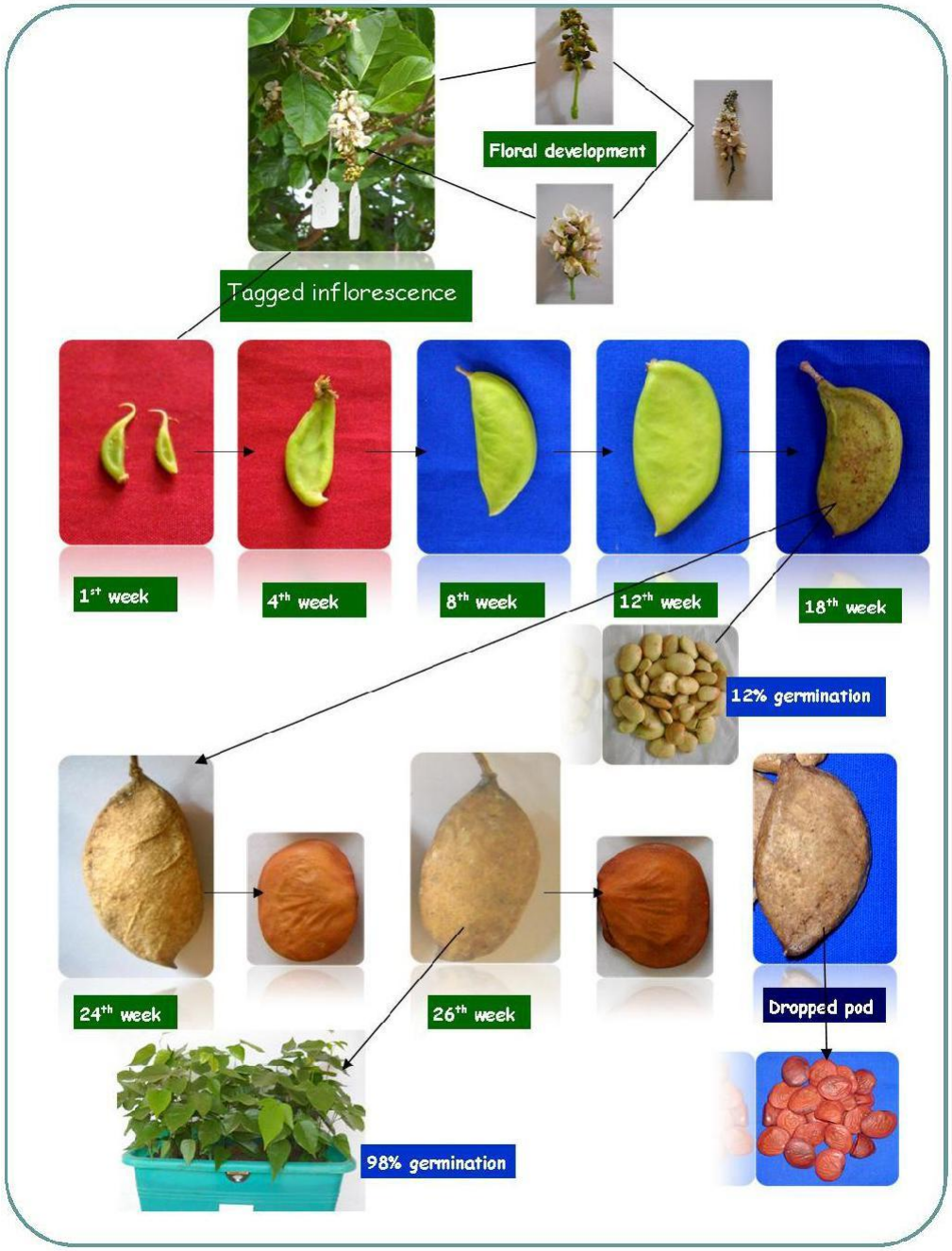

Figure 1. Pod and seed development in *Pongamia pinnata*.

to collect the fruits.

Varying periods of maturation for crops were also reported by Srimathi (1997) for fruit crops and Kathiravan (2004) for Jatropha. The pod maturity in this location (Coimbatore) was observed from mid-December to February. But Raut et al. (2011) reported that variation in fruit characteristics vary from place to place towards the point of maturation due to the variable environmental factors. Pollock and Roos (1972) reported that, after fertilization, as a result of cell division, there is a significant increase in seed size forming the embryonic cells that receive assimilates from the parent plant. During this period, seed moisture content remains constant and high. The significant decrease in seed moisture content occurs at the end of maturation when changes in cell membrane structure organization occurs as well as increases the enzyme synthesis in preparation for successful germination. Chlorophyll degradation and

Table 2. Studies on seed development and maturation in *Pongamia pinnata.*

Pod and seed development (weeks after anthesis)	Color of pod	Pod length (cm)	Pod breadth (cm)	Pod weight (g)	Color of seed	Germination (%)
1st week	Light green	1.0	0.2	0.6	Greenish white	-
2nd week	Light green	1.2	0.3	1.2	Greenish white	-
3rd week	Light green	1.3	0.4	1.3	Greenish white	-
4th week	Light green	1.4	0.5	1.5	Greenish white	-
5th week	Light green	1.6	0.6	1.7	Greenish white	-
6th week	Light green	1.8	0.9	2.1	Greenish white	-
7th week	Light green	1.9	0.9	2.7	Greenish white	-
8th week	Light green	2.0	1.0	3.0	Greenish white	-
9th week	Light green	2.2	1.2	3.2	Yellowish white	-
10th week	Light green	2.3	1.2	4.0	Yellowish white	-
11th week	Light green	2.4	1.3	4.2	Yellowish white	-
12th week	Light green	2.5	1.4	4.4	Yellowish white	-
13th week	Light green	2.6	1.6	4.5	Yellowish white	-
14th week	Light green	2.8	1.8	4.6	Yellowish white	-
15th week	Light green	2.9	1.9	4.7	Yellowish white	-
16th week	Dark green	3.1	2.1	4.9	Light brown	5 (12.9)
17th week	Dark green	3.3	2.2	5.0	Light brown	7 (15.3)
18tn week	Dark green	3.5	2.2	5.1	Light brown	12 (19.6)
19th week	Dark green	3.6	2.4	5.2	Light brown	15 (22.5)
20tn week	Dark green	3.7	2.5	5.4	Light brown	35 (36.2)
21st week	Greenish brown	3.9	2.6	5.5	Light brown	56 (48.5)

Table 2. Cont.

22nd week	Greenish brown	4.1	2.7	5.6	Light brown	60 (50.8)
23ra week	Yellow	4.3	2.9	5.7	Light brown	78 (62.1)
24th week	Yellow	4.4	2.9	5.9	Light brown	88 (69.8)
25th week	Light brown	4.7	3.0	6.2	Brown	92 (73.7)
26th week	Light brown (dry pod)	5.2	3.1	6.4	Brown	98 (84.2)
27 week	Dark brown (Pods dropped)	4.9	3.1	6.0	Dark brown	93 (74.3)
Mean	-	2.9	1.7	4.1	-	24 (21.1)
CD (P=0.05)	-	0.18	0.17	0.19	-	5.6 (5.2)

Figures in parentheses are arc sine transformed values

ethylene production is one of the reasons for the changing occurs in pod colours from initiation to maturity (Ward et al., 1995). Maturity has important implications in harvesting fruits at proper stage so as; the seeds have developed quality attributes (Singh et al., 2011).

Evaluation of harvest index based on fruit colour

Fresh fruit colours variations observed for fruit and seed characters, seed quality characters and for their performance in the present study were highly significant (Table 3). Standardization of fruit colours for each of the forestry species would be of immense help to seed collectors of forest trees as collection is a laborious process in these species owing to their inaccessibility for manual collection and the longer duration of harvesting period. Fruit colour is considered as an index of seed maturation particularly in forestry by several researchers (Khullar et al., 1991, Srimathi, 1997). Willan (1985) also revealed that fruit colours would serve as a tool for collection of good quality seeds in forestry as the persons involved in the collection process are mostly lacking in technical skill.

The analysis on colours of *Pongamia pinnata* fruit, on seed and seedling quality characters revealed that the growth measurements increased with changes in fruit colours. The fruit and seed moisture content decreased from yellow to dark brown as 27.4 to 17.6 per cent and as 21.2 to 8.9 per cent respectively. In seed characters, the seed length and breadth were highest with yellow fruits (2.5 and 1.9 cm respectively) and it reduced slightly with advances in fruit colours from light brown (2.4 and 1.7 cm respectively) to dark brown (2.2 and 1.6 cm). The highest seed weight of 100 seeds from green fruits recorded as 242.4g, however with light brown and dark brown pods it reduced as 232.1 and 192.4g respectively. The seed germination recorded by the fruits collected with various colours revealed that the seeds of yellow fruits were 80 per cent germination, while the seeds of light brown and dark brown (dropped pods) fruits recorded 96 and 91 per cent respectively suggesting the collection of light brown fruits for obtaining the seeds with maximum germination capacity. The vigour of seed evaluated through root length, shoot length, fresh weight, dry weight and vigour index were also higher in seeds obtained from light brown fruits and was followed by dark brown, and yellow fruits. The light brown colour of the fruit with higher seed and seedling quality characters were also coincided with the earlier results on seed maturation, where at 26 weeks after anthesis, the pod colour changes as light brown and that coincided with the seed germination recorded as the highest. Gurunathan et al. (2009), Kathiravan (2004), Kaushik et al. (2001) in *Jatropha curcas*, Srimathi et al. (2001) in Jamun found similar seed quality variations with fruit colours indicating that fuit colour would serve as an indication of seed maturation in pungam.

Conclusion

From the above results the study concluded that pungam trees were produced an average 35 flowers per inflorescence. Pod and seed set was very low as 3-4 percent though 80 percent of

Table 3. Influence of fresh fruit colour on *Pongamia pinnata* seed and seedling quality characters.

Fruit colours/character	Yellow	Light brown	Dark brown	SED	CD (P=0.05)
Fruit characters					
Fruit length (cm)	4.9	4.4	3.9	0.1	0.3
Fruit breadth (cm)	2.7	2.3	2.1	0.1	0.2
Fruit moisture content (%)	27.4	21.8	17.6	0.9	1.9
Seed moisture content (%)	21.2	15.9	8.9	0.5	1.0
Seed and seedling quality characters					
100 seed Weight (g)	242.4	232.1	192.4	2.2	4.6
Seed length (cm)	2.5	2.4	2.2	0.05	0.1
Seed breadth (cm)	1.9	1.7	1.6	0.04	0.1
Germination (%)	80 (63.6)	96 (79.4)	91 (72.9)	1.6 (1.9)	3.3 (4.1)
Shoot length (cm)	28.9	31.8	30.6	0.8	1.8
Root length (cm)	18.8	20.1	22.2	1.1	2.3
Fresh weight (10 seedlings^{-1})(g)	44.7	51.5	47.2	0.8	1.6
Dry weight (10 seedlings^{-1}) (g)	12.7	14.6	14.3	0.4	0.9
Vigour index^{1}	3827	5177	4808	132.5	278.3
Vigour index^{2}	1509	1977	2019	93.4	196.2
Vigour index^{3}	1016	1412	1301	40.3	84.6

Figures in parentheses are arc sine transformed values

pods setting seed. Pungam fruits (pods) attain physiological maturation 26 to 27 weeks after anthesis, and the seed collected at this stage recorded higher quality seed and seedling characters. Fruit (pod) colours of pungam vary as green, light brown and dark brown at the time of bulk collection for seeds. Among the three colours of fresh fruits the highest germination of 96 per cent was recorded for seeds of light brown fruits suggesting the collection of light brown fruits for obtaining the seeds with maximum germination capacity, which could also serve as harvest index for collection of quality seeds in pungam.

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