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Full length Research paper

Need for quality seed for raising quality seedlings indicated by fruit colour serving as harvest Index

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Quality characters are influenced by many factors and among them the most warranted is the physiological maturation of the seed. In rising any plantation seed serve as the base material, which is characterized for its potentiality only based on its quality, which is spoken in terms of seed germination and seed vigour. Tree crops which are having continuous flowering habit, the maturity levels vary with seeds and collection of fruit for seeds is also mostly depends on ground collection. Hence studies in four important oil yielding tree species viz., *Pongamia pinnata, Simarouba glauca, Azardirachta indica* and *Madhuca longifolia* for identification of visual indices for seed maturation based on fruit colour that correlates well with seed quality. The results revealed that seeds of dark brown fruits of *P. pinnata* (96%), dark pink fruits of *S. glauca* (95%), yellow fruits of *A. indica* (100%) and greenish black fruits of *M. longifolia* (80%) registered maximum germination and seedling vigour in terms of seedling growth characters compared to fruits of various colours in all the species indicating that fruit colour could serve as the symptom of harvest index that could be employed for the selection of quality fruits for obtaining quality seeds.

Key words: Fruit colour, harvest index, seed quality, biofuel tree crops.

INTRODUCTION

Trees are generally propagated through seeds expecting long life and efficient tap root system though vegetative propagation is possible. The basic characters of seed used for regeneration is the quality of the seed which are characterized in terms of physical, physiological and health status of the seed but is widely variable as it is influenced by many factors that influence the seed quality. Quality seed possess higher seed germination and higher vigour characters normally measured in terms of seedling growth. These characters could be achieved with the seed if it is harvested at optimum stage, which is normally designated as the physiological maturity of the seed (Copeland and McDonald, 1995). Physiological maturation is the stage at which the seed attains the maximum dry weight that is accompanied with maximum seed and seedling quality characters in terms of seed germination and seedling vigour (Agrawal, 1995) and are widely indicated through physical indices such as size, colour and weight, which are much useful in perennial crops (Willan, 1985) as seed collection is mainly from ground than from the tree due to difficulties faced on climbing the tree for selection of fruit. Researchers (In *Jatropha curcas*, Gurunathan et al., 2009, in Neem, Ponnuswamy, 1993; Bharathi, 1999, in Simaruba, Sekar, 2005 and in *Calophyllum inophyllum* (Punnai), Ponnuswamy et al., 2005) revealed that fruit colour serve as an indicator of seed maturation in tree crops as it is easily identifiable and applicable and the results are also

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highly reproducible and also suggested collection of fruits based on fruit colour could as an reliable index of seed maturation and for selection of quality seed for raising plantation. Many of the underutilized and oil bearing tree species are identified as biofuel crops and are extensively researched on their potentiality in biofuel production as they could serve as alternate to fossil fuel and could meet the ever increasing demand on oil production.

The major oil yielding trees identified for their potentiality to meet oil requirement are *Pongamia pinnata* (L.) Pierre (Indian beech tree or Pungam) belongs to the family Fabaceae, *Simarouba glauca* DC (Paradise tree) belongs to the family of Simaroubaceae, *Azadirachta indica* A. Juss (Neem) belongs to the family Meliaceae and *Madhuca longifolia* J.F.Macbr (Indian butter tree or Mahua) belongs to the family of Sapotaceae. These trees also had multipurpose utility as medicinal trees and are getting more importance in plantation forestry. In all these tree seeds are serves as the basic propagative material, indirectly emphasizing the need for quality seed for raising quality seedlings. As indicated earlier fruit colour serves as harvest index for obtaining quality seed, studies were initiated to identify the fruit colour for collection of quality seed in all the four biofuel crops.

MATERIALS AND METHODS

Seed source

The experiment was conducted in the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore (11°1′6″N 76°58′21″E), India during the year 2011-2012. Seed sources for each of the crop were identified based on the abundance distribution of the species within the Indian state of Tamil Nadu. Bulk collections of fruits from ground were made in trees, which contained medium aged morphologically superior trees identified as plus trees. Fresh fruits of *Pongamia pinnata* were collected as bulk from Karamadai (11.24251°N 76.96009°E) seed source, while the fruits of *Simarouba glauca* were from Mettupalayam (11.30°N 76.95°E) seed source. Fruits of *Azardirachta indica* were collected from Pattukkottai (10.43°N 79.32°E) seed source, while that of *Madhuca longifolia* were from Panruti (11.77°N 79.55°E) seed source of Tamil Nadu, India.

Experimentation and materials

Fresh fruits from all the study species were categorized into different colours based on availability as show in Table 1 and Figures 1 to 4. The fruits of each colour category were observed for fruit morphological characters (fruit length (cm) fruit breadth (cm), fruit moisture content (%) using vernier caliper, while the fruit moisture content was computed based on fresh weight and the oven dry weighing ten fruits of seven replications. The seeds were dry extracted in pungam and mahua, while wet extracted in neem and paradise tree. The extracted seeds were shade dried for a day and observed for the physical characters viz., seed length (cm) and breadth (cm) using vernier caliper (AOAC, 1960) and the 100 seed weight using eight replicates of 100 seeds as per ISTA (2010). Based on fresh weight and the oven dry weight (103°C for 17 h), the seed moisture content was calculated.

The seeds were extracted from the differentially categorized colour fruits of each of the species were germinated in sand media at the depth of 2 cm in a germination room maintained at 30°C and 95% RH as per the recommendations of ISTA (2010) using 4 × 100 seeds. After the germination period of 25 for pungam, 23 for paradise tree and neem, and 41 days of mahua, the seeds were evaluated for germination based on normal seedlings (proper development of root and shoot). The germination of seeds was expressed in percentage using the formula (mean of normal seedling produced/total number of seeds sown × 100 in each of the replication). Ten normal seedlings in each of the replications, colour categories and seedlings were randomly selected and measured for root length (cm) and shoot length (cm) were measured using the measuring scale and the fresh weight of the seedlings were weighed in a weighing balance and were dried in an hot oven maintained at 85°C for 48 h and weighed in a weighing balanced and reported as dry weight of the seedlings for 10 seedlings. Vigour index values are of the totality in expression of seed quality characters as per Abdul-Baki and Anderson (1973) and the vigour index values were also computed adopting the following formulae and reported as index values without any unit.

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)

Statistical analysis

The data gathered for various colour categories for all the four crops were analyzed as per F test of significance at 0.5% level adopting the statistical design complete randomized design (CRD) for understanding the level of significance among the fruit, seed and seedling quality characters of fruit colour variations . The non-significant results were indicated as NS.

RESULTS AND DISCUSSION

Standardization of fruit colour 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. Hence in most of the species fruits are collected from ground for extraction of seed. The fruits of ground collection vary with their physical characters. Fruit colour is considered as an easily identifiable visual index of seed maturation in most of the forestry tree species (Khullar et al., 1992). Willan (1985) also revealed that fruit colour would serve as a tool for collection of good quality seeds in forestry as the persons involved in the collection process, are mostly lack in technical skill. Srimathi (1997) and Parameswari (1999) also considered seed colour also as the visual index of seed maturation. In the present study also similar observation were made, where the pod colour changes from green to greenish yellow to yellowish brown to brown, where the yellowish brown colour coincide with the predicted day of maturation in conjunction with physical and physiological status of seed.

Highly significant variations were obtained for all the characters observed for the fruit colour variations in all

Table 1. Fresh fruits from study species.

Species	Fruit colours identified
Pongamia pinnata	Green, dark brown and brown
Simarouba glauca	Yellowish green, light pink and dark pink
Azadirachta indica	Greenish yellow, yellow and yellowish brown
Madhuca longifolia	Green, greenish black and black

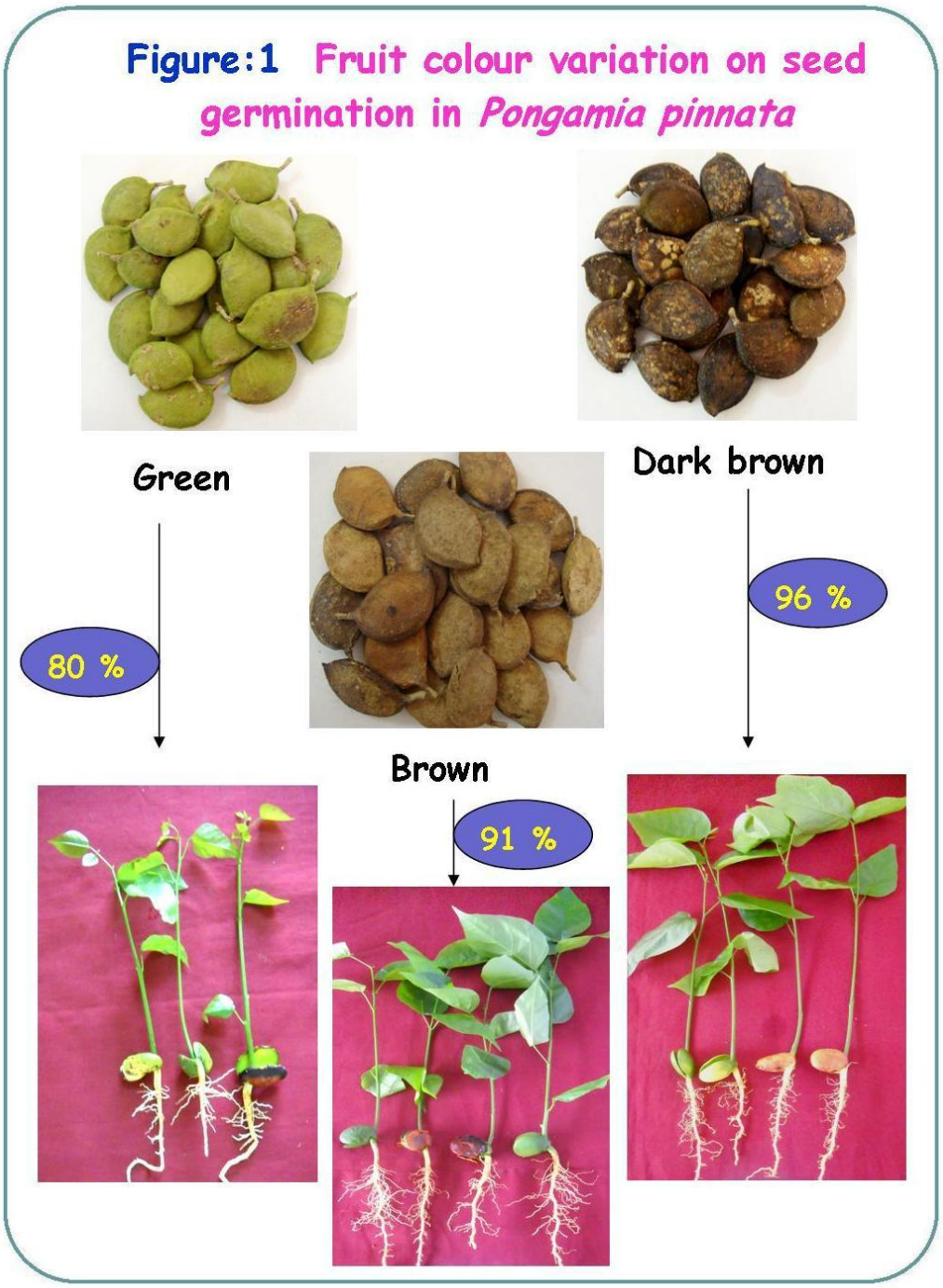

Figure 1. Fruits colour variation on seed germination in *Pongamia pinnata*.

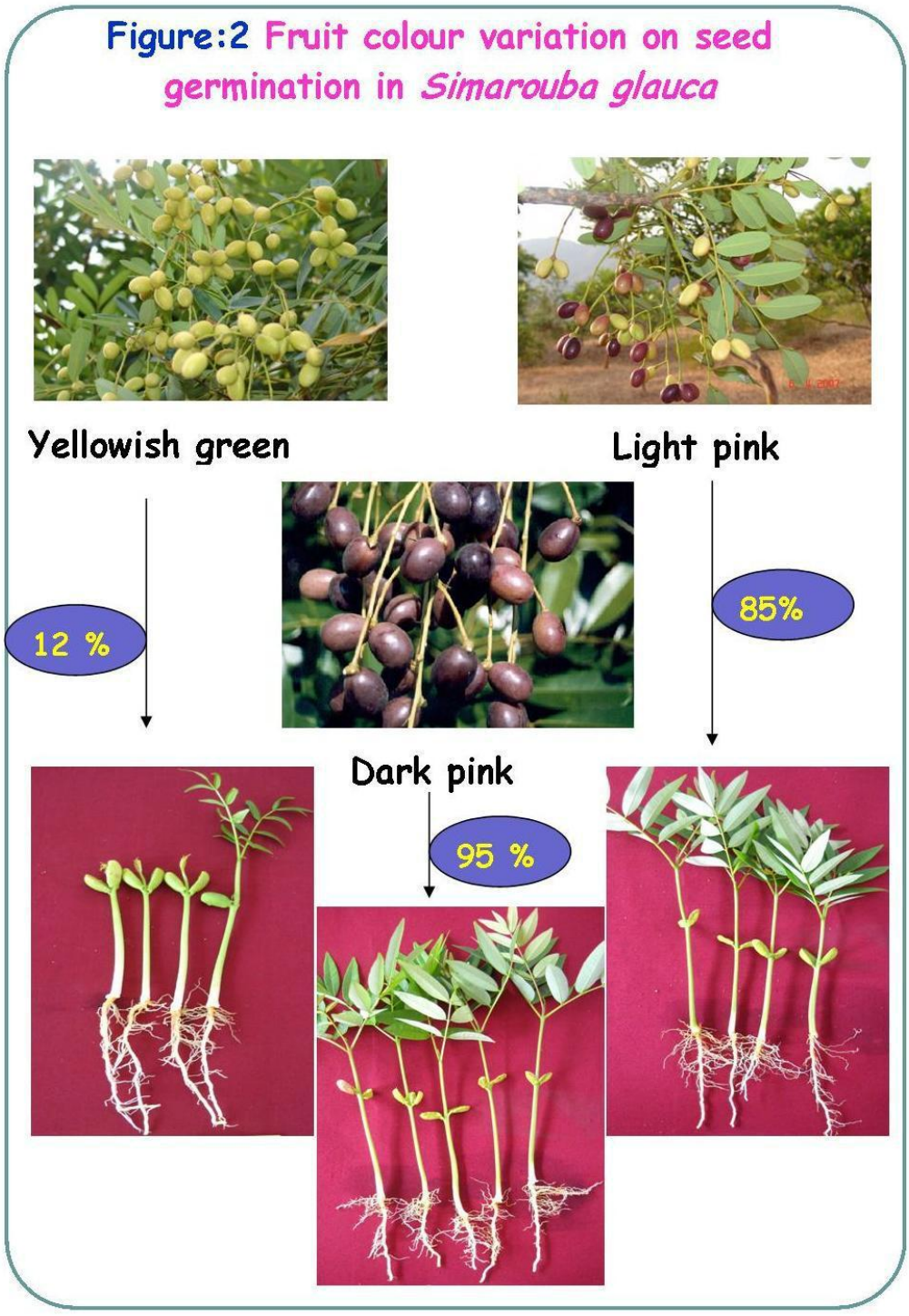

Figure 2. Fruits colour variation on seed germination in *Simarouba glauca.*

crops (Tables 2, 3, 4 and 5). In pungam (Table 2), the variations observed with the pericarp of fruit expressed significant variations in the physical measurements of the fruit, which decreases with the disappearance of green colouration indicating the deletion of chlorophyll content which is highly expected with advances in maturation due to the accumulation of anthocyanin pigmentation and the drying of seed as indicated through the lesser moisture content (Srimathi et al., 2001). The fruit and seed moisture content decreased from green to brown as 27.4

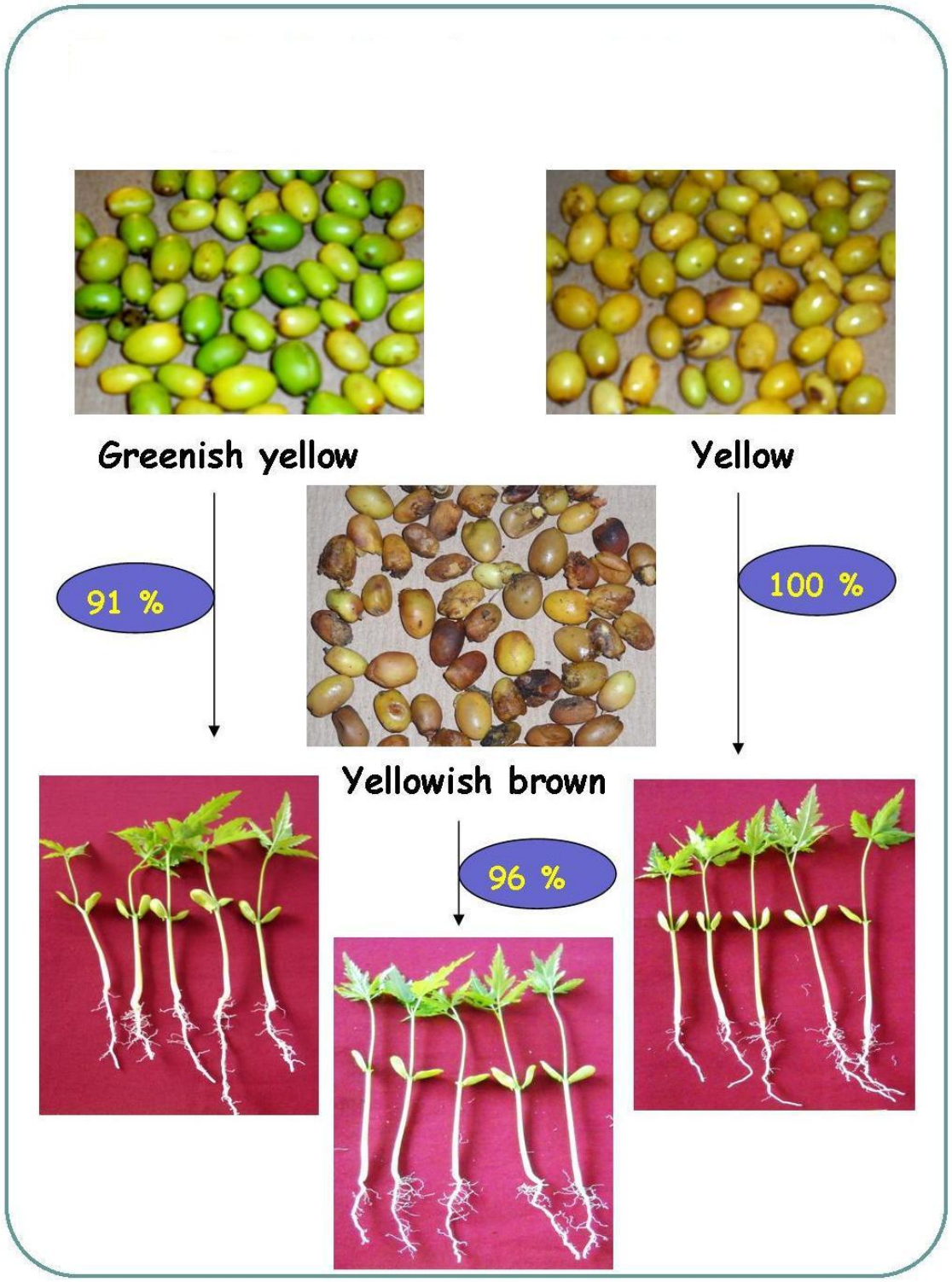

Figure 3. Fruits colour variation on seed germination in *Azadirachta indica.*

to 17.6% and as 21.2 to 8.9%, respectively indicating the completion of accumulation of food material and initiation of desiccation as expressed by ant other orthodox seed (Natarajan and Srimathi, 2008). In seed characters, the seed length and breadth were highest with green fruits (2.5 and 1.9 cm, respectively) and it reduced slightly with advances in fruit colour from brown (2.4 and 1.7 cm respectively) to dark brown (2.2 and 1.6 cm). In

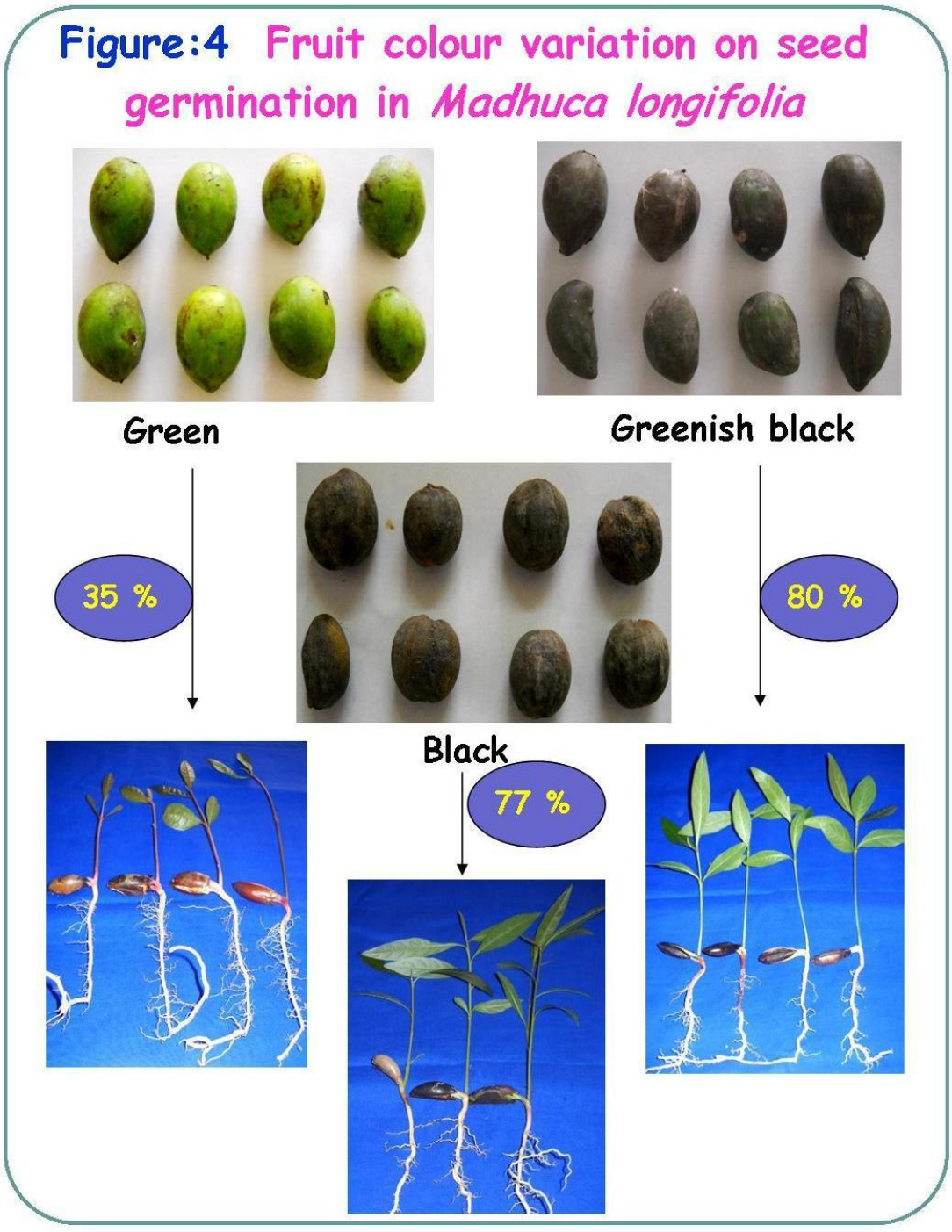

Figure 4. Fruits colour variation on seed germination in *Madhuca longifolia.*

supportive of the earlier characters the highest seed weight of 100 seeds was observed with green fruits (242.4 g), which decreased with brown and dark brown as 232.1 and 192.4 g, respectively indicating the maximization of dry matter accumulation with brown fruits. The seed germination recorded by the fruits of various colours revealed that the seeds of green fruits were 80% germination, while the seeds of brown and brown colored fruits recorded the germination of 96 and 91%, respectively (Table 2) suggesting that brown fruits obtained the maximum physiological efficiency in terms of germination and vigour in terms of root length, shoot length, fresh weight, dry weight and vigour index, while it was lesser with green as it is still in growth phase and in

Table 2. Fresh fruit colour on *Pongamiapinnata* (Fabaceae) fruit morphology, seed and seedling quality characters during the year 2011-2012.

Fruit colours / characters	Green	Dark brown	Brown	Mean	SEd	CD (P=0.05)
Fruit length (cm)	4.9	4.4	3.9	4.4	0.1	0.3
Fruit breadth (cm)	2.7	2.3	2.1	2.4	0.1	0.2
Fruit moisture content (%)	27.4	21.8	17.6	22.3	0.9	1.9
Seed moisture content (%)	21.2	15.9	8.9	15.3	0.5	1.0
100 seed weight (g)	242.4	232.1	192.4	222.3	2.2	4.6
Seed length (cm)	2.5	2.4	2.2	2.4	0.05	0.1
Seed breadth (cm)	1.9	1.7	1.6	1.7	0.04	0.1
Seed germination (%)	80 (63.6)	96 (79.4)	91 (72.9)	89.0 (72.0)	1.6 (1.9)	4.1
Shoot length (cm)	28.9	31.8	30.6	30.4	0.8	1.8
Root length (cm)	18.8	20.1	22.2	20.4	1.1	2.3
Fresh weight (10 seedlings^{-1})(g)	44.7	51.5	47.2	47.8	0.8	1.6
Dry weight (10 seedlings^{-1})(g)	12.7	14.6	14.3	13.9	0.4	0.9
Vigour index^{1}	3827	5177	4808	4604	132.5	278.3
Vigour index^{2}	1509	1977	2019	1835	93.4	196.2
Vigour index^{3}	1016	1412	1301	1243	40.3	84.6

Figures in parentheses are arc sine transformed values, SEd = Standard Error, CD (P=0.05) = Critical Difference at the level significance (5 %), 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 3. Fresh fruit colour on *Simarouba glauca* (Simaroubaceae) fruit morphology, seed and seedling quality charactersduring the year 2011-2012.

Fruit colours / characters	Yellowish green	Light pink	Dark pink	Mean	SEd	CD (P=0.05)
Fruit length (cm)	2.3	2.3	1.9	2.2	0.1	0.2
Fruit breadth (cm)	1.4	1.5	1.2	1.4	0.1	0.2
Fruit moisture content (%)	69.2	74.4	75.1	72.9	1.1	2.3
Seed moisture content (%)	46.3	34.3	29.4	36.7	0.7	0.5
100 seed Weight (g)	138.0	120.2	112.4	123.5	1.0	2.2
Seed length (cm)	1.7	1.8	1.6	1.7	0.06	0.1
Seed breadth (cm)	1.1	1.1	1.0	1.1	0.04	0.09
Germination (%)	12 (21.7)	85 (67.2)	95 (78.4)	64.0 (55.8)	0.6 (2.1)	4.4
Shoot length (cm)	17.2	21.5	23.8	20.8	0.8	1.6
Root length (cm)	7.7	19.1	11.3	12.7	0.4	0.8
Fresh weight (10 seedlings^{-1})(g)	16.3	19.1	22.7	19.4	0.7	1.5
Dry weight (10 seedlings^{-1}) (g)	2.1	2.2	2.9	2.4	0.1	0.3
Vigour index^{1}	310	2794	4082	2395	104.5	219.6
Vigour index^{2}	96	965	1816	959	45.2	95.0
Vigour index^{3}	25	187	274	162	13.3	28.0

Figures in parentheses are arc sine transformed values, SEd = Standard Error, CD (P=0.05) = Critical Difference at the level significance (5 %), 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).

dark brown pods which was over matured and the seed senescence had set in reducing the seed quality characters. In jamun (Srimathi et al., 2001), in ber and emblica (Srimathi, 1997) and in tamarind also researchers reported similar seed quality variations due to fruit colour obtained bulk fruits obtained from ground.

The three different fruit colours (yellowish green, light pink and dark pink) of *Simarouba glauca* also (Table 3) depicted a significant variation for physical characters of fruit and seed and for the physiological seed and seedling quality characters including vigour index. The fruit moisture content increased from yellowish green (69.2%)

Table 4. Fresh fruit colour on *Azardirachta indica* (Meliaceae) fruit morphology, seed and seedling quality characters during the year 2011-2012.

Fruit colours / characters	Greenish yellow	Yellow	Yellowish brown	Mean	SEd	CD (P=0.05)
Fruit length (cm)	1.9	1.9	1.0	1.6	0.06	0.1
Fruit breadth (cm)	0.9	0.7	0.5	0.7	0.07	0.2
Fruit moisture content (%)	59.3	50.2	19.2	42.9	0.8	1.6
Seed moisture content (%)	14.0	13.5	9.2	12.2	0.4	0.9
100 seed Weight (g)	42.1	36.6	19.0	32.6	0.8	1.6
Seed length (cm)	1.2	1.0	0.9	1.0	0.05	0.1
Seed breadth (cm)	0.5	0.5	0.4	0.5	0.03	0.06
Germination (%)	91 (71.6)	100 (89.9)	96 (75.3)	95.7 (78.9)	1.3 (2.3)	4.8
Shoot length (cm)	14.2	14.6	13.9	14.2	0.5	NS
Root length (cm)	5.9	6.2	5.4	5.8	0.3	0.6
Fresh weight (10 seedlings^{-})(g)	9.9	10.1	8.7	9.6	0.5	1.1
Dry weight (10 seedlings^{-1}) (g)	2.0	2.1	1.6	1.9	0.2	NS
Vigour index^{1}	1827	2085	1853	1922	47.2	99.2
Vigour index^{2}	535	622	521	559	28.0	58.8
Vigour index^{3}	178	207	155	180	17.1	35.9

Figures in parentheses are arc sine transformed values, NS- Non significant, SEd = Standard Error, CD (P=0.05) = Critical Difference at the level significance (5 %), 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).

to dark pink fruits (75.1%), while the seed moisture content of these fruits, respectively decreased from yellowish green (46.3%) to dark pink fruit (29.4%), might be due to the ripening of fruit in case of fruit moisture content and due to desiccation of seeds as expressed in seed moisture content (Jerlin et al., 2001; Justice and Bass, 1978; Malarkodi and Srimathi, 2007).

The highest fruit length was recorded for both yellowish green and light pink (2.3 cm) and thereafter it reduced in dark pink (1.9 cm) and the trend was similar with breath also. The seed and seedling quality characters concern, the maximum value of 100 seed weight recorded for yellowish green fruit seeds (138.0 g) followed by light pink fruit seeds (120.0 g) and dark pink fruit seeds (112.4 g). The highest value of seed length and seed breadth scored for light pink fruit seeds (1.8 cm) and both yellowish green and light pink fruit seeds (1.1 cm), respectively. The seedling quality characters *viz.,* germination (%), shoot length (cm), root length (cm), fresh weight (10 seedlings^{-1}) (g), dry weight (10 seedlings^{-1}) (g), vigour index^{1}, vigour index ^{2} and vigour index^{3} increased from yellowish green fruits to dark pink fruits as 12 to 95%, 17.2 to 23.8 cm, 7.7 to 19.1 cm, 16.3 to 22.7 g, 2.1 to 2.9 g, 310 to 4082, 96 to 1816 and 25 to 274 respectively (Table 3).

In neem, the fruit characters *viz.,* fruit length, fruit breadth, fruit moisture content and seed moisture content were maximum for greenish yellow fruit (1.9 and 0.9 cm, 59.3 and 14.0%, respectively) followed by yellow and yellowish brown (Table 4). Seed quality characters viz., seed weight (100 seeds) (42.1 g), seed length (1.2 cm) and seed breadth (0.5 cm), the highest value was observed in greenish yellow fruit seeds followed by yellow and yellowish brown fruit seeds. Germination (100%), shoot length (14.6 cm), root length (6.2 cm), fresh weight of 10 seedlings (10.1 g), dry weight of 10 seedlings (2.1 g), vigour index^{1} (2085), vigour index^{2} (622) and vigour index^{3} (207) of seedling quality characters were recorded for seeds of yellow fruits.

The fruit characters of *Madhuca longifolia* viz., fruit length, fruit moisture content and seed moisture content decreased with fruit maturation colour as green (4.7 cm, 66.8 and 58.8%) to black (3.0 cm, 52.0 and 39.8%). However for fruit breadth the maximum value was recorded with greenish black fruit (3.2 cm) followed by green (2.9 cm) and black (2.8 cm). In seed characters, the seed length and breadth were highest with green fruits (3.6 and 1.5 cm respectively) and it reduced slightly with advances in fruit colour from greenish black (3.5 and 1.5 cm respectively) to black (3.1 and 1.3 cm). The highest seed weight of 100 seeds from green fruits was recorded as 201.6 g; however, greenish black and black fruit scored 190.4 and 177.6 g respectively. The seed germination recorded by the fruits collected with various colour revealed that the seeds of green fruits were 35% germination, while the seeds of greenish black and black fruits recorded the germination of 80 and 77% respectively suggesting the collection of greenish black 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 greenish black fruits and was followed black, and green fruits (Table 5).

Carlson (1973) and Delouche (1973) expressed that during maturation the photosynthates moved into the developing ovule through extensive network of vascular tissue located throughout the open integument and this vascular system of the integumentary was destroyed as the seed mature, which coincided with the turning of seed

Table 5. Fresh fruit colour on *Madhuca longifolia* (Sapotaceae) fruit morphology, seed and seedling quality characters during the year 2011-2012.

Fruit Colours / characters	Green	Greenish black	Black	Mean	SEd	CD (P=0.05)
Fruit length (cm)	4.7	4.4	3.0	4.0	0.2	0.4
Fruit breadth (cm)	2.9	3.2	2.8	3.0	0.2	NS
Fruit moisture content (%)	66.8	54.5	52.0	57.8	1.6	3.4
Seed moisture content (%)	58.8	46.5	39.8	48.4	1.2	2.5
100 seed Weight (g)	201.6	190.4	177.6	189.9	1.5	3.2
Seed length (cm)	3.6	3.5	3.1	3.4	0.2	0.4
Seed breadth (cm)	1.5	1.5	1.3	1.4	0.06	0.1
Germination (%)	35 (36.2)	80(63.5)	77 (60.7)	64.0 (53.5)	2.4(1.6)	3.3
Shoot length (cm)	14.1	16.2	15.8	15.4	0.6	1.3
Root length (cm)	15.8	16.9	16.8	16.5	0.4	0.9
Fresh weight (10 seedlings^{-1}) (g)	41.4	46.3	43.7	43.8	1.1	2.4
Dry weight (10 seedlings^{-1}) (g)	10.3	14.3	12.6	12.4	0.7	1.4
Vigour index^{1}	1043	2657	2525	2075	89.7	188.5
Vigour index^{2}	553	1359	1299	1070	45.1	94.7
Vigour index^{3}	363	1151	978	830	60.4	126.9

Figures in parentheses are arc sine transformed values, NS- Non significant, SEd = Standard Error, CD (P=0.05) = Critical Difference at the level significance (5 %), 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).

coat colour. In horticultural crops, Kolhe and Chavan (1964) in bhendi and Manohar (1970) in lablab and Sundaralingam (1995) in carrot also similar coincidence of fruit colour was observed with recommended days for maturation after anthesis.

The observations reported by Ponnuswamy (1993), Bharathi et al. (1996), Bharathi (1999), Maithani et al. (1989) and Sacande et al. (1996) in *Azardirachta indica*, Sekar (2005) in *Simarouba glauca*, Gurunathan et al. (2009), in *Jatropha curcas* were in supportive of the above findings insisting on consideration of fruit colour as an index of seed maturation particularly in forestry. Standardization of fruit colour for each of the perennial species would be of immense help to seed collectors of forest trees as collection is a laborious process in many species, owing to their inaccessibility for manual collection and the longer duration (Maithani et al., 1989; Sacande et al., 1996). Sacande et al. (1996) and Maithani et al. (1989) also reported that the collection of seeds based on fresh fruit colour had significant influence on the storability of neem seeds.

Conclusion

The study revealed that the overall performance of the seeds of dark brown fruits of *P. pinnata,* dark pink fruits of *S. glauca*, yellow fruits of *Azardirachta indica* and greenish black fruits of *Madhuca longifolia* were found to be perform better compared to other fruit colours, highlighting the suitability of colours for selection of good quality seeds as it could be the maturation colour of these species. Hence during harvest, colours specific to species should be considered for obtaining elite seedlings from nursery.

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