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Fruit maturity, storage time and pre-sowing water treatment effect on emergence and seedling vigour parameters of bitter wild mango (Irvingia wombolu Vermoesen) seeds in the nursery

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Keywords

Fruit maturity colour;
Storage time;
Soaking time;
Irvingia wombolu;
Traits improvement.

Abstract

Poor germination and seedling establishment as well as unavailability of seeds are major problems in sustainable production of *Irvingia wombolu*. Hence the need to find the right colour fruit maturity, storage time and pre-sowing water treatment on emergence and seedling vigour parameters of bitter wild mango seeds with the aim of improving this multipurpose fruit tree species. Five maturity colour which include green, yellow, yellowish green, greenish brown and dark brown were subjected to 4 water soaking regimes (0, 12, 24 and 36 h) and 4 room temperature storage duration (0, 2, 4 and 6 weeks). Completely randomized design factorial with three replications was used. Data on seed emergence capacity, seedling length, seed vigour index (SVI), stem diameter and number of leaves were subjected to analysis of variance. Results shows that significant differences ($P<0.05$-$P<0.01$) were observed in the five quality traits observed due to differences in fruit colour, soaking time and storage time. The three- way interaction between fruit colour, soaking time and storage time were significant (($P<0.05$-$P<0.01$) for all the characters. Dark brown fruit recorded the best in terms of emergence, seedling vigour index, stem diameter and leaf while yellow colour fruit had the best in terms of plant height. Zero-hour soaking had the highest in seedling emergence, seedling vigour index and leaf number while 12 h soaking gave the best effect in terms of plant height and stem diameter. Dark brown and yellow colour fruit of *I. wombolu* are recommended and short duration of soaking for 0-12 h will enhance the plant height and stem diameter.

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1. Introduction

The African forests are rich in natural resources and have tremendous biodiversity particularly in trees that provide food, fuel, fibre, medicines and various other products. The sustainability of these natural resources has been the concern of many [1], particularly with the continued clearing and selective exploitation of forests [2]. Among these natural resources is the highly ranked *Irvingia wombolu*.

Irvingia wombolu (locally known as *ogbono*) is a highly sought-after multipurpose fruit tree ranked as the most important species among all indigenous fruit trees for its food and commercial value in West and Central Africa [3-6]. This species produces edible nuts widely marketed within and outside the region [1, 2] and form an important diet providing carbohydrates, oils and proteins to enhance health and nutrition [7]. In spite of its importance in providing economic and livelihood benefits to subsistence farmers, it is still not widely cultivated as most of the edible fruits and kernels are still got from the wild. Therefore, they are becoming increasingly difficult to collect due to deforestation and old tree age [1].

Poor germination and seedling establishment are major problems in *I. wombolu* production both in Nigeria and other West African countries [8]. The production of this highly sought multi-purpose tree species is also limited by long period of seed sown to germinate [9, 10]. Although, the poor germination of the seeds has also been attributed to the recalcitrant nature of the seeds [11], there is limited knowledge on the seed physiology [12]. Fruit maturity, soaking time and storage period have been identified as factors that affect germination performance in tree and crop species [10, 13]. Scanty information exists on the effect of these factors on seed germination performance in *I. wombolu*.

Seed is the common propagation material for most tropical tree species [14]. Propagation from seed is inexpensive and usually effective, and is therefore a viable method for their *ex-situ* conservation [15]. An understanding of seed physiology could expectedly contribute to the effort of seed-based *in-situ* conservation as well as *ex-situ* cultivation [16]. The proper handling of seed through the processes of ripening or maturation, collection, processing, storage, dormancy, stratification and germination is required for success in producing vigorous seedlings. Often, seed ripening and collection does not correspond with the time of seedling pro-

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duction, while some species do not produce seeds all year round. Seed storage is therefore vital to secure the supply of good quality and quantity seeds for planting [17, 18]. Previous studies have shown that soaking of *Azardirachta indica* seeds for 1, 12 and 24 h resulted in increasing rate of seed germination [19, 20], also reported the highest percentage germination of 50, when *Diallium guinensis* seeds were soaked in hot water for 30 min. Earlier researchers have also shown that mechanical scarification and soaking are features that enhance germination in seeds of tropical trees [8, 21-23].

Very little information exists on the effect of fruit colour as well as water soaking treatment on seed germination of *I. wombolu* seeds. Thus, it will be necessary to determine which fruit maturation stage of *I. wombolu* will yield good viable seeds and seeds of good vigour. Therefore, this research work was carried out to evaluate the effect fruit colour and pre-sowing water treatment on germination and seedling vigour performances of *I. wombolu* seeds and to investigate the effect of storage time to improve germination and seedling vigour performances of *I. wombolu* seeds.

2. Materials and methods

2.1. Seeds collection

Fruits of *I. wombolu* were collected from Okhuesan in Esan South local government area of Edo State, Nigeria. The collected fruits were divided into five bases on colour as: green, yellow, greenish brown, yellowish-green and dark brown. Each category was made up of 360 fruits, making a total of 1800 seeds for the experiments. The fruits were extracted manually with the use of knife by peeling off the pulp after which washing with water was done. The extracted seeds were air dried for three days and then stored in the laboratory.

2.2. Experimental site

The experiments were carried out at the Physiology and Tree Breeding Nursery of Forestry Research Institute of Nigeria (FRIN). Headquarters Jericho, Ibadan. FRIN is located on the longitude 07023'18''N to 07023'43''N and latitude 03051'20''E to 03051'43''E. The climate of the study area is the West African monsoon with dry and wet seasons. The dry season is usually from November through March and is characterized by dry cold wind of harmattan. The wet season usually starts from April to October with occasional strong winds and thunderstorms. Mean annual rainfall is about 1548.9 mm, falling within approximately 90 days. The mean maximum temperature is 31.90C, minimum 24.20C while the mean daily relative humidity is about 71.9% [24].

2.3. Experimental procedure and design

The factorial experiment was laid down in a Completely Randomized Design (CRD) with three replications. There were three factors: fruit maturity colour (5), soaking time (4) and storage time (4) as follows.

Fruit maturity colour: The fruit maturity colours include:

1. Treatment 1 = green colour
2. Treatment 2 = yellow colour
3. Treatment 3 = greenish brown colour
4. Treatment 4 = yellowish green colour and
5. Treatment 5 = dark brown colour.

Each of the colours had 360 seeds for the entire test.

Soaking Treatment

The fruits of different colours were soaked in water at two weeks interval for the following soaking regimes:

1. 0 h soaking as control (that is no soaking)
2. 12 h soaking
3. 24 h soaking
4. 36 h soaking

Ninety (90) seeds from each of the fruit colours were soaked for each of duration indicated making a total 450 seeds for each soaking duration and a total of 1800 seeds for this study.

Storage time (weeks)

The extracted seeds from each fruit colour were stored for between 0 and 8 weeks as follows:

1. Week 0 (immediately after extraction)
2. Week 2 after extraction
3. Week 4 after extraction
4. Week 6 after extraction
5. Week 8 after extraction

A total of 360 seeds from the five fruit colours were used per week and 1800 for the entire storage duration.

2.4. Experimental procedure and maintenance of Seedlings

Nursery pots were filled with top soil and one seed sown directly at a uniform depth of 5cm into the pots. The seedlings were watered regularly to avoid water stress. A nursery shed was provided to avoid excessive water from the rain and also to protect the seeds from direct sunlight. Weeding was carried out as when due.

Seed quality assessment

The following seeds quality traits:

1. Seed emergence capacity: this was assessed twice a week at the commencement of seed emergence.
2. Seedling length: this was assessed weekly starting at the 10 days at the commencement of seed emergence
3. Seed Vigour Index (SVI): The Seedling Vigour Index was calculated by multiplying percentage germination by the average of plumule length after seven days of germination and divided by one thousand (1000) [13].
4. Stem diameters was observed weekly starting from 10 days after seedling emergence
5. Number of leaves: Physical count of leaves was done twice a week for the period of observation.

2.5. Statistical analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SPSS version 2000 and significant treatment means were separated using Turkey at 5% level of probability.

3. Results and Discussion

3.1. Results

Table 1 presents the summary of analysis of variance showing the effect of fruit colour, soaking time and storage time on seed quality traits of *I. wombolu*. The effect of each of the factors on all traits measured were significant ($p<0.05$). The interaction effect of soaking time and fruit colour was highly significant for all the

parameters examined. Also, the interaction effect of storage time and fruit colour and the effect of interaction between storage time and soaking time were highly significant for all the parameters. The three- way interaction between fruit colour, soaking time and storage time were highly significant for all the characters.

Tableau 1 : Summary of Analysis of variance (ANOVA) showing the effects of fruit colour, soaking time and storage time on seed quality traits of *I. wombolu* seeds

Sources of variation	Df	Seedling emergence	Plant height	Seedling vigour index	Stem diameter	Number of leaves
Storage Time (S)	3	564.011**	2139.47**	872.85**	47.48**	111.09**
Soaking time (T) 3	3	936.60**	196.01**	90.67**	2.24*	2.89*
Fruit colour (C)	4	565.05**	380.06**	52.43**	5.713**	4.59*
TxC	12	280.15**	76.35**	24.66**	4.06**	11.52**
SxC	12	2007.91**	159.13**	114.68**	5.59**	21.112**
SxT	6	281.26**	139.95**	52.64**	5.13**	14.56**
SxTxC	36	340.44**	145.54**	51.53**	4.25**	7.13**

* Significant at 0.05 probability level, ** Significant at 0.0 1 probability level

Table 2 shows that there were significant differences in seed quality parameters among the fruit colours. The yellow seeds had the highest seedling emergence of 65.8% while seeds from green fruit colour had the lowest germination value of 46.5%. Seeds from yellowish green fruit had the highest plant height (20.8 cm), followed by greenish brown seeds with plant height value of 10.0 cm, which was closely followed by yellowish green seeds with plant height of 19.7 cm. Green seeds had plant height of 18.9 cm. The seeds from dark brown fruit had the lowest plant height of 13.7 cm. The diameter of all the fruit colours except seeds from green and dark brown colour fruit had similar and higher stem diameter values.

Number of leaves was highest in yellow fruit which is significantly different from values recorded for seedlings from yellowish-green (4.5) and dark-brown (4.6) fruits whereas seedlings from green colour fruits had the lowest (3.98) number of leaves.

For the soaking time effect (Table 2), seeds that were not soaked had the highest seedling emergence of 56.1%, followed by seeds soaked in water for 12 h with seedling emergence of 49.9%, followed by seeds soaked for 24 h. Seeds soaked in water for 36 h had the lowest seedling emergence of 47.4%. The highest stem diameter value of 10.7 mm was recorded for seeds soaked in water for 12 h. Seeds soaked in water for 36 hours gave the lowest value of 8.5. For plant height and seedling vigour, it was observed that seeds soaked for 12 h had the highest value of 20.7 cm and 3.7 cm, followed by seeds that were not soaked with value of 19.5 cm and 3.5 cm respectively followed by seeds soaked for 36 h with the value of 17.3 cm and 3.4 respectively. Seeds soaked in water for 24 h had the lowest value of 16.9 cm and 3.2 respectively. The storage time effect (Table 2) indicated that seeds that were not stored (0w eek) had the highest seedling emergence, plant height, seedling vigour index, stem diameter and number of leaves while 6 weeks of storage had the lowest values.

Tableau 2 : Main effects of fruit colour, soaking time and storage time on seed quality parameters evaluated in *I. wombolu* seeds

Fruit colour	Seedlings emergence	Plant height	Seedling vigour index	Stem diameter	Number of leaves
Green	46.46 ^{d}	18.88 ^{b}	3.53^{b}	9.39 ^{b}	3.98 ^{c}
Yellow	65.81a	20.79 ^{a}	3.61 ^{a}	11.01 ^{a}	4.71 ^{a}
Greenish brown	60.12 ^{b}	19.98 ^{a}	3.59 ^{b}	10.29 ^{a}	4.23^{bc}
Yellowish-green	60.35 ^{b}	19.73 ^{a}	3.57^{b}	11.09 ^{a}	4.53^{ab}
Dark-brown	64.91^{a}	13.74^{c}	3.62^{a}	9.68^{b}	4.63^{ab}
Soaking time (h)					
0	56.05^{a}	19.52^{b}	3.48 ^{b}	11.45 ^{a}	4.50^{a}
12	49.85 ^{b}	20.72 ^{a}	3.66 ^{a}	10.67 ^{b}	4.35^{a}
24	49.05 ^{b}	16.93 ^{c}	3.20 ^{d}	9.60 ^{c}	4.17 ^{b}
36	47.38 ^{c}	17.32 ^{c}	3.35 ^{c}	8.64 ^{d}	4.08^{c}
Storage Time (weeks)					
0	57.75 ^{a}	22.97 ^{a}	4.10 ^{a}	13.21 ^{a}	5.45 ^{a}
2	49.33 ^{b}	21.25 ^{b}	3.58 ^{c}	10.56 ^{c}	4.55 ^{b}
4	47.27 ^{c}	20.46 ^{b}	3.88 ^{b}	11.99 ^{b}	4.23 ^{a}
6	36.98 ^{d}	9.80 ^{c}	2.13 ^{d}	4.61 ^{d}	2.47 ^{c}

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

Table 3 shows the effect of fruit colour, soaking time and storage time on seedling emergence of *I. wombolu* seeds. The result showed that dark-brown seeds that were not soaked nor stored gave the highest corresponding value of seedling emergence of 98% which was closely followed by dark brown seeds stored for 0 week and soaked for 12 h with a seedling emergence of 87%. Lowest seedling emergence of 12% was recorded for dark-brown seeds that were soaked for 12 and 36 h and stored for 6 weeks.

Table 4 shows the effect of fruit colour, soaking time and storage time on plant height of *I. wombolu* seeds. The result showed that seeds from yellow fruits stored for 0 weeks, soaked for 0 h had the highest plant height of 32.03 cm whereas the lowest plant height of 1.34 cm was recorded for dark brown seeds stored for 6 weeks after 12 h of soaking.

Table 5 shows the effect of fruit colour, soaking time and storage time on stem diameter of *I. wombolu* seeds. The result showed that seeds from dark-brown fruits after soaking for 12 h had the highest stem diameter of 8.88 cm whereas the lowest stem diameter of 2.96 cm was obtained from seeds of dark fruits soaked for 12 h. After 2 weeks of storage, seeds from yellow fruits at 24 and 36 h of soaking, dark fruit at 0 h soaking and yellowish green at 12 h of soaking gave the highest stem diameter. At 4 weeks of storage, seeds from dark-brown fruits gave the highest stem diameter of 4.90 cm after soaking for 36 hours. Seeds from dark after soaking for 12 h gave the least stem diameter of 2.90 cm. After 6 weeks of storage, seeds from green fruits gave the highest stem diameter 5.05cm after 36 hours of soaking. Seeds from green and yellow fruits after soaking for 24 h gave the lowest stem diameter of 2.11 cm.

Table 6 shows the effect of fruit colour, soaking time and storage time on number of leaves of *I. wombolu* seeds. The result showed that seeds from dark-brown fruits had the highest number of leaves of 10 at 0 h soaking whereas the lowest number of leaves

Tableau 3 : Effects of fruit colour, soaking time and storage time on seedling emergence of *I. wombolu* seeds

Fruit colour	Soaking time (h)	Storage time(weeks) 0	2	4	6
Green	**0**	60^{d}	53^{b}	53^{e}	33^{f}
	12	47^{g}	40^{d}	46^{f}	40^{e}
	24	51^{f}	40^{d}	60^{d}	33^{f}
	36	40^{h}	40^{d}	67^{c}	40^{e}
Yellow	**0**	73^{c}	53^{b}	40	33
	12	53^{e}	40^{d}	60^{d}	40^{e}
	24	60^{d}	47^{c}	73^{b}	40^{e}
	36	60^{d}	53^{b}	47^{f}	33^{f}
Greenish brown	**0**	47^{g}	40^{d}	80^{a}	47^{d}
	12	60^{d}	40^{d}	60^{d}	40^{e}
	24	60^{d}	60^{a}	53^{e}	33^{f}
	36	40 h	47^{c}	53^{e}	40^{e}
Yellowish-green	**0**	73^{c}	60^{a}	73^{b}	40^{e}
	12	53^{e}	53^{b}	47^{f}	67^{a}
	24	60^{d}	47^{c}	60^{d}	47^{d}
	36	53^{e}	33^{e}	68^{c}	60^{b}
Dark brown	**0**	98^{a}	60^{a}	53^{e}	52^{c}
	12	87^{b}	60^{a}	40^{g}	12^{g}
	24	73^{c}	60^{a}	40^{g}	13^{g}
	36	73^{c}	60^{a}	40^{g}	12^{g}

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

Tableau 4 : Effect of fruit colour, soaking time and storage time on plant height of *I. wombolu* seeds

Fruit colour	Soaking time (h)	Storage time (weeks) 0	2	4	6
Green	**0**	28.17b	29.50 a	22.43b	2.64f
	12	28.50b	24.33b	18.17d	12.67c
	24	25.17c	5.63e	22.50b	6.30e
	36	21.17d	24.96b	22.96b	14.20 c
Yellow	**0**	32.03 a	24.40b	25.06b	3.77e
	12	22.17c	27.36ab	28.93 a	24.97 a
	24	25.03c	15.73d	23.27b	11.13d
	36	23.87	24.27 b	19.13d	8.15d
Dark	**0**	27.57b	22.50b	20.23c	15.67c
	12	23.07c	17.80d	20.47c	17.70b
	24	20.97d	23.50b	23.33b	2.23f
	36	24.30c	20.30 c	20.33 c	21.90ab
Yellowish-green	**0**	28.60b	20.53c	22.17b	18.90b
	12	22.03c	27.13ab	21.63c	24.63a
	24	18.80d	3.90e	24.47b	25.93a
	36	22.30c	24.13b	14.37e	1.89f
Dark brown	**0**	22.03c	24.13b	14.37e	3.81e
	12	23.03c	21.30 c	20.20 c	1.34f
	24	19.70d	18.40d	11.40f	3.65e
	36	17.10f	16.06 d	11.80f	6.32e

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

was recorded for seeds from yellow fruits, dark fruits and dark-brown fruits after soaking for 24 h. At 2 weeks of storage, seeds from green fruits had the highest number of leaves of 7.67 after soaking for 0 h. Also, the same fruit colour recorded the lowest number of leaves of 1.67 after 24 h of soaking. After 4 weeks of storage, seeds from dark-brown had the highest number of leaves of 10.00 after soaking for 24 h whereas the lowest number of leaves was obtained with seeds from green colour fruits after 12 h of soaking. At 6 weeks of storage, the result showed that seed from yellowish-green after 24 h of soaking recorded the highest leaf number of 5.33 whereas seeds from dark-brown fruits,

Tableau 5 : Effect of fruit colour, soaking time and storage time on stem diameter of *I. wombolu* seeds

Fruit colour	Soaking time (h)	Storage time (weeks) 0	2	4	6
Green	**0**	4.48^{d}	4.15^{b}	4.16^{c}	4.37^{b}
	12	4.71^{d}	3.70^{c}	3.26^{e}	3.84^{c}
	24	4.11^{e}	4.33	3.55^{e}	2.133
	36	4.37^{e}	4.15^{b}	3.99^{d}	5.05^{a}
Yellow	**0**	4.67^{d}	3.47^{d}	4.25^{bc}	2.60^{f}
	12	3.64^{f}	3.09^{e}	3.9^{d}	4.25^{b}
	24	4.66^{d}	4.72^{a}	4.34^{b}	2.11^{g}
	36	4.05^{e}	4.67^{a}	3.30^{e}	2.45^{f}
Dark	**0**	6.23^{c}	4.82^{a}	4.20^{c}	3.93^{c}
	12	2.96^{g}	3.51^{d}	2.91^{f}	4.50^{b}
	24	4.18^{e}	3.41^{d}	4.59^{b}	3.32^{e}
	36	3.85^{f}	3.41^{d}	3.30^{e}	4.47^{b}
Yellowish green	**0**	4.12^{e}	3.45^{d}	3.82^{d}	3.67^{d}
	12	4.90^{d}	4.90^{a}	4.15^{c}	3.90^{c}
	24	4.68^{d}	3.91^{c}	4.68^{a}	4.10^{c}
	36	3.70^{f}	3.75^{c}	3.23^{e}	2.69^{f}
Dark brown	**0**	7.49^{b}	3.60^{d}	3.20^{e}	2.60^{f}
	12	8.88^{a}	4.15^{b}	3.59^{d}	3.07^{e}
	24	4.24^{e}	3.88^{c}	3.84^{d}	3.700^{d}
	36	3.58^{f}	3.12^{e}	4.95^{a}	4.33^{b}

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

irrespective of the soaking time, had the lower number of leaves when compared to other of similar effect.

Tableau 6 : Effect of fruit colour, soaking time and storage time on number of leaves of *I. wombolu* seeds

Fruit colour	Soaking Time (h)	Storage time (weeks) 0	2	4	6
Green	**0**	6.00^{b}	7.67^{a}	4.67^{c}	1.13^{c}
	12	5.00^{c}	3.68^{d}	1.67^{e}	3.33^{b}
	24	5.00^{c}	1.67^{e}	4.33^{c}	1.87^{c}
	36	6.00^{b}	5.67^{b}	4.00^{c}	4.00^{b}
Yellow	**0**	6.33^{b}	5.33^{b}	4.67^{c}	3.00^{b}
	12	6.33^{b}	4.00^{c}	4.67^{c}	4.00^{b}
	24	4.33^{d}	5.67^{b}	5.00^{c}	1.67^{c}
	36	5.67^{c}	4.67^{b}	4.00^{c}	1.89^{c}
Dark	**0**	6.00^{b}	4.67^{b}	4.67^{c}	3.00^{b}
	12	5.33^{c}	4.33^{c}	4. 33^{c}	4.67^{a}
	24	4.33^{d}	4.00^{c}	4.67^{c}	1.54^{c}
	36	4.67^{d}	4.33^{c}	4.67^{c}	4.00^{b}
Yellowish- green	**0**	7.00^{b}	4.00^{c}	4.67^{c}	4.00^{b}
	12	6.00^{b}	5.00^{c}	6.67^{b}	3.33^{b}
	24	5.00^{c}	2.96^{d}	6.00^{b}	5.33^{a}
	36	5.00^{c}	5.67^{b}	3.67^{d}	3.89^{b}
Dark brown	**0**	10.00^{a}	5.50^{b}	5.00^{c}	1.44^{c}
	12	6.00^{b}	5.00^{c}	3.00^{d}	1.68^{c}
	24	4.00^{d}	4.37^{c}	10.00^{a}	1.09^{c}
	36	6.33^{b}	6.33^{ab}	9.00^{a}	3.96^{b}

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

Result in table 7 shows the effect of fruit colour, soaking time and storage time on seedling vigour index of *I. wombolu* seeds. The result revealed that seeds from dark-brown fruits had the highest seedling vigour index after soaking for 0 and 12 h whereas seeds from dark fruits after 0 h soaking and seeds from green fruits after 36 h soaking, gave the lowest seedling vigour index. At 2

weeks of storage, seeds from yellow fruits gave the highest seedling vigour index of 17.39 which was not significantly different from values of 16.79 obtained at 0 h soaking time with seeds from green fruits. The lowest seedling vigour index of 2.27 was obtained from seeds from green fruit after soaking for 24 hours. After 4 weeks of storage, seeds from dark colour fruits gave the highest seedling vigour index of 18.00 at 0 h soaking which was not statistically different from the values of those obtained with yellow and yellowish-green fruits, while seeds from dark-brown fruits after soaking for 24 and 36 h gave the least value of seedling vigour index. After 6 weeks of storage, seeds from yellowish-green after 12 h soaking gave the highest seedling vigour index of 16.50.

Tableau 7 : Effect of fruit colour, soaking time and storage time on seedling vigour index of *I. wombolu* seeds

Fruit colour	Soaking	Storage time (weeks)			
	time (h)	0	2	4	6
Green	**0**	16.80^{b}	16.96^{ab}	11.88^{c}	8.17^{c}
	12	13.39^{c}	9.73^{c}	8.356^{d}	5.06^{d}
	24	12.86^{c}	2.27^{e}	13.50^{b}	1.18^{e}
	36	8.53^{e}	9.73^{c}	15.37^{b}	5.73^{d}
Yellow	**0**	18.29^{b}	17.39^{a}	12.89^{c}	1.24^{e}
	12	14.19^{c}	14.98^{b}	14.99^{b}	10.07^{b}
	24	11.04^{d}	13.87^{b}	16.86^{a}	4.49^{d}
	36	11.75^{d}	6.37^{d}	8.99^{d}	2.42^{e}
Dark	**0**	7.37^{e}	11.12^{c}	18.00^{a}	9.57^{b}
	12	13.97^{c}	7.18^{d}	12.37^{c}	7.14^{d}
	24	12.56^{c}	14.10^{b}	12.40^{c}	1.18^{e}
	36	9.80^{d}	9.54^{c}	10.79	8.84^{c}
Yellowish-green	**0**	17.26^{b}	14.96^{b}	16.07^{a}	11.36^{b}
	12	11.61^{d}	14.22^{b}	10.19^{c}	16.50^{a}
	24	12.33^{c}	14.71^{b}	12.19^{c}	7.96^{c}
	36	11.78^{d}	7.58^{d}	9.79^{d}	1.38^{e}
Dark brown	**0**	21.83^{a}	14.48^{b}	7.61^{d}	1.88^{e}
	12	20.10^{a}	10.01^{c}	8.08^{d}	8.47^{c}
	24	14.32^{c}	11.04^{c}	4.56^{e}	2.91^{e}
	36	12.42^{c}	9.64^{c}	4.72^{e}	9.08^{c}

Means with the same alphabet along a column are statistically the same according to Turkey at 5% level of probability.

3.2. Discussion

This study revealed that significant differences were observed among fruit colours, storage time and soaking time for seedlings emergence, seedling vigour index, plant height, stem diameter and number of leaves of bitter bush mango. This implies that growth and development of *I. wombolu* were affected by fruit colours, storage time and soaking time. Consequently, improvement in seed and seedling vigour could be achieved by giving due consideration to fruit colour from which seeds of bitter bush mango are obtained as well as post seed extraction factors such as storage duration and soaking period. This is in line with Adebisi et al who, reported significant differences in different fruits maturity colours and hydro priming periods in *Gmelina arborea* tree [13].

The high germination obtained from seeds not stored and progressive decline in germination for stored seeds with storage time indicated that seed of bitter bush mango lose viability during storage. Previous studies had shown that tree species loses viability when stored under room temperature [25]. The thee-way interaction effect between fruit colour, soaking and storage, indicated that fruit colour and soaking time modulated the seed viability and seedling vigour of *I. wombolu* under storage. Significant effect of fruit maturity colour and soaking time has earlier been reported by Adebisi et al in *Gmelina arborea* [13]. A previous report showed that seeds from the yellow fruit colour had the highest viability in *Gmelina arborea*.

On the water soaking effect, no soaking (control) treatment had the highest seedling emergence, seedling vigour level and number of leaves when compared with other soaking hours. With increase in the water soaking time to 12 h resulted in higher plant height and stem diameter above other water soaking hours. Soaking the seed for over 12 h resulted in decline in all the plant characters examined thereby suggesting harmful effect of excessive soaking on the seeds. Since the 12 h soaking performed better than 24 and 36 h of soaking suggests that the seed of *I. wombolu* require an optimal level of moisture rather than full saturation to activate the embryo in order to commence the process of cell division, differentiation and multiplication to germinate and grow into a seedling phase as optimal level of soaking time has enhanced effects on germination and growth of plant. This is in line with some researcher who documented the differential responses of seeds to hydro priming time as reported by Adebisi et al in *Gmelina arborea* and by Nya et al on *I. gabonensis* [13, 26].

The study revealed that the effect of storage was highly pronounced as sowing seeds immediately after seed extraction irrespective of fruit colours without storing have the superior seed emergence and seedlings vigour traits and storing for more than 6 weeks gave declined seed emergence. This is due to the fact that most recalcitrant seeds loose moisture on storage and this subsequently leads to poor germination as well as vigour. Waren and Adams further affirm that in recalcitrant seeds, as the storage period increases, moisture content further reduces, respiration rate declines and this phenomenon leads to decline in seeds viability as well as vigour [27].

This finding agrees with the findings of Kandari et al who reported a steady decrease in viability of tropical tree species when stored beyond 2 weeks [25]. On the mechanisms and kinetics of seed aging, Walters observed that in seed deferment, seed lose vigour and became more sensitive to stresses upon germination. Eventually, seed lose the ability to germinate [28]. However, the factors which determine the rate of aging are temperature and moisture content at which seeds are stored [28].

On the effect of fruit colour, seeds from dark brown had the highest seed quality in terms of emergence, seedling vigour index, stem diameter and number of leaves whereas seed from yellow fruits had the highest in terms of plant height. This is due to the fact that seeds from dark brown and yellow colour represent the fully matured fruit of bitter bush mango. This is in line with Adebisi et al who observed that seeds obtained from yellow fruits of Gmelina arborea tree gave superior seed germinating performance and good seedling vigour level, irrespective of soaking hours [13].

Furthermore, seeds from dark brown fruits sown immediately after extraction with short duration of soaking for 0 to 12 h were found with increase seedling emergence and seedling vigour parameters. This is also in line with the conclusion of Alaje et al who observed significant effect of fruit colour on the seed quality

traits of *I. gabonensis* and concluded dark brown recorded the best in terms of seed germination, plant height and collar diameter while yellow fruit seeds had the highest seedling vigour index and number of leaves [29].

Conclusion

Significant differences were observed in the five quality traits observed due to differences in fruit colour, soaking time and storage time. Fruit colour of dark brown recorded the best in terms of emergence, seedling vigour index, stem diameter and leaf while yellow colour fruit had the best in terms of plant height. Zero hours soaking (control) treatment recorded the highest in seedling emergence, seedling vigour index and number of leaves while 12 h soaking gave the best effect in terms of plant height and stem diameter. The effect of storage was highly significant as sowing immediately without storing recorded the best in all the traits examined and storing for more than 6 weeks gave no emergence.

Recommendations

Irvingia wombolu being a recalcitrant seed cannot be stored for up to 6 weeks before planting regardless of the soaking duration instead little duration storage of 0-2 weeks is recommended. The seeds from the dark brown and yellow colour which indicate the fully ripe fruit of *I. wombolu* are recommended for regeneration or sowing. Short duration of soaking of *I. wombolu* seeds for 0-12 h will enhance the plant height and stem diameter. *Irvingia wombolu* is one of the highest rank multipurpose fruit tree species which has not being fully propagated in plantations.

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