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Seedling emergence and growth of pawpaw (*Carica papaya*) grown under different coloured shade polyethylene

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A b s t r a c t. Seven nursery shades made of blue, yellow, green, red, and colourless polyethylene, and palm frond (*Elaeis guineensis* Jacq) and non-shaded frame were evaluated for their effects on seedling emergence and early growth of two fruit morphotypes of 'Sunrise Solo' pawpaw cultivar. Seedlings grown under different polyethylene colours showed significant ($P<0.05$) effect on days to 50% seedling emergence, percentage emergence at first emergence, and percentage weekly emergence for the first six weeks after planting. The highest percentage emergence (72%) was observed under green shade colour compared to palm frond and non-shaded seedlings that gave 63 and 60%, respectively. Also, leaf-count, plant height, stem girth and vigour - monitored for five months in the nursery and field - were responsive to different colours used as nursery shade. Plant height, stem girth, and vigour were higher in seedlings grown under green polyethylene shade. Comparison of fresh weight of root, stem, leaf and total dry matter yield of seedlings grown under different nursery shades showed that seedlings grown under green shade gave the best result. Temperature and light intensity varied significantly ($P<0.05$) under the different nursery shades, and these differences in microclimate are implicated for the variability in seedling emergence and growth pattern. Evidence from the study revealed that green polyethylene used as nursery shade enhanced seedling emergence and growth quality of the test crops compared to other colours of polyethylene and palm fronds.

K e y w o r d s: pawpaw, nursery, plasticulture, seedling, quality

INTRODUCTION

Tropical fruit crops and other plantation crops are traditionally established with seedlings previously grown in a nursery. A nursery allows cultivation and establishment of seedlings under controlled conditions. But, the growing conditions under the nursery setup are under the control of the nurseryman; therefore, seedling quality is invariably determined by the quality of cultural practices engaged by the nurseryman. Lamont and O'Connell (1987) reported that the quality of container-grown ornamental plants is, in broad terms, dependent on the physical and chemical composition of the medium, the growing environment, and plant management such as watering, pest and disease control. Raising seedlings through a nursery assures that orchards/plantations are established with superior quality planting materials which have distinct advantages of better survival and growth. Besides, this practice ensures economy of seed and permits intensive management that reduces infestation of pathogens and attacks of insect pests on seedlings (Baiyeri, 2003).

Plants utilize radiant energy as a source of energy and have photo systems to process the energy (Hart, 1988). The term photo-synthetically active radiation (PAR) is used to describe the range of visible light which is responsible for plant growth. Therefore, interrupting any colour of the visible spectrum will reduce plant growth. Different polyethylene colours used as shade reflect different spectra of the visible light and transmit some spectra of the visible light with consequent effect on physiological behaviour of plant.

Plants respond to the intensity of blue light, and reducing the blue light will encourage plant elongation and leggy growth. This response is not relative to the strength of radiation in any other part of the spectrum. Rather it is the absolute intensity of the blue light which influences plant height and quality. There is a more important response which depends on the relative intensities of red (660 nm) and far-red (around 730 nm) light and increasing the amount of far-red light relative to the red makes plants grow tall and spindly, while increasing the red relative to the far-red does

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the reverse. If the red to far-red ratio is increased significantly, significant changes in plant habit and height reduction can be achieved (Hopkins, 1999).

Light reflectivity may affect not only crop growth but also insect response to the plants grown on mulch. Examples are yellow, red, and blue mulches, all of which increased green peach aphid populations (Orzolek and Murphy, 1993). The yellow colour was especially attractive to pests and drew increased number of striped and spotted cucumber beetles. Yellow coloured mulch has been used in greenhouses to monitor insect. Mulches with painted aluminium have been shown to repel certain aphid species and reduce or delay the incidence of aphid-borne viruses in summer squash (Lamont *et al*., 1990). Coloured mulches affect crop development and yield by manipulating the light quality around plants and changing the red far-red ratio (Decoteau *et al*., 1989; 1990). In addition, coloured mulches may have a different transmission of infrared radiation, resulting in a difference in soil temperatures (Ham *et al*., 1993). Separation of light quality from temperature effects of coloured mulches on growth remains difficult to assess. In addition, productivity using mulches varies among the geographic regions and crops (Giacomelli *et al*., 2000).

Pomper *et al.* (2002) found that the growth of containerized pawpaw seedlings was positively influenced by low to moderate shading with polypropylene shade fabric (51% outdoors) and low shading (33%) in the greenhouse. Low to moderate shading of pawpaw seedlings grown outdoors greatly increased the leaf number, total leaf area, increased the chlorophyll concentration in leaves and total plant dry weight compared to non-shaded seedlings, indicating that commercial nurseries can improve production of containerized pawpaw seedlings by using a shading regime outdoors. Shading of field-planted pawpaw trees has been suggested to assist in the establishment of young trees (Layne, 1996).

In Nigeria and elsewhere in tropical Africa palm frond is probably the oldest and most common nursery shade used; in some agricultural experimental stations colourless polyethylene is a commonly used shade for nursery seedlings. However, as a result of worldwide global warming with concomitant higher radiation reaching the earth surface, there is a need to re-evaluate the conventional nursery shade covers with alternative covers with a view of reducing the high insolation (and its scorching effect) reaching the nursery plants.

In this study therefore, using two fruit morphotypes of 'Sunrise Solo' pawpaw cultivar as test crops, seven nursery shade types were evaluated to determine their effects on seedling emergence pattern, seedling quality and early growth of seedlings after field re-establishment.

MATERIALS AND METHOD

Two experiments, nursery and field studies, were conducted at the Department of Crop Science, University of Nigeria, research farm between February and August 2005. The nursery experiment was an evaluation of the effects of seven nursery shades on seedling emergence and early growth qualities of seedlings of two fruit morphotypes (morphological types) of 'Sunrise solo' pawpaw (*Carica papaya*) cultivar. The second experiment was a field study to evaluate the growth qualities of seedlings raised under different nursery shades during the first three months of field re-establishment.

The two pawpaw morphotypes evaluated were round-shaped (red pulp) and oblong-shaped (orange pulp). Fruits were obtained from the local market. Their morphological and horticultural attributes were determined. The seven nursery shades evaluated were blue, yellow, green, red, and colourless polyethylene, and palm frond and non-shaded frame. The different polyethylene colours were obtained from the same local market; the polyethylene sheets were of similar thickness.

Seeds extracted from the pawpaw fruits were washed in water to remove the mucilage. Thereafter, the seeds were air dried for 12 h before planting; ten seeds were planted per 2.5 l bucket. Soil-less growth medium composted from ricehull and poultry manure (3:2 v/v) was used. The nursery frame had 2 x 2 x 1 m dimensions for each shade type. There were fifteen replications per each morphotype per nursery shade, that is, thirty buckets per each frame. Six weeks after seed sowing, seedlings were thinned to one per bucket. Growth quality traits at thinning, one month after thinning and three weeks after hardening (*ie* acclimatization to the natural non-shaded environment) were measured. Also, dry matter yield of seedlings as influenced by morphotypes and nursery shades was determined. The nursery experiment was a factorial in completely randomized design (CRD). Factor A was the seven nursery shades while Factor B was the two pawpaw morphotypes. There was a relatively high incidence of variegated grasshopper (*Zonocerus variegatus*) in the yellow shade, which was controlled by spraying baygon (a local insecticide). The air temperature (°C) and light intensity (W m^{-2}) inside the nursery shades were measured at about 1.5 m above the ground level. The temperature readings were recorded three times a week while the light intensity readings were recorded Wednesday every week, three repeated times per nursery shade. Temperature and light intensity measurements were taken between 12 and 14 h (local time). Light intensity was measured with a solarimeter obtained from the Energy Research Center, University of Nigeria, Nsukka, Nigeria. The thermometer for temperature reading was hung at the centre of each nursery shade.

Seedlings derived from fourteen treatment combinations (seven nursery shades by two pawpaw morphotypes) were transplanted to the field 10 weeks after emergence. Seedlings were planted out in the field on May 27th, 2005, in a single-row plot of three plants replicated three times per morphotype within nursery shade. Field cultural practices were performed as needed. Experimental design was a factorial in a randomized complete block design (RCBD). Growth parameters, which included plant height, stem diameter, number of leaves and vigour, were measured monthly during the first three months (June to August, 2005) after transplanting. Plant vigour scoring was based on indices developed solely for the study (Table 1). Data on rainfall, temperature, relative humidity, and solar radiation during the field study are shown in Table 2.

Plant data collected were subjected to analysis of variance following the procedures outlined for factorial in CRD and RCBD. Principal component analysis (PCA) was performed on nursery shade temperature and light intensity, and all seedling emergence and growth traits were measured to identify most important determinant trait for seedling quality as influenced by nursery shade colour. Although factors other than light and temperature would influence seedling emergence and growth, for this study only light and temperature obviously varied due to the micro-environment changes created by the different shade types. Data were analysed with GENSTAT 5.0 Release 4.23DE (GENSTAT, 2003).

RESULTS

Variability in morphological and horticultural characteristics of the two pawpaw morphotypes evaluated is shown in Table 3. The oblong fruit type had orange pulp whereas the pulp colour of the round morphotype was red. Hundred fresh seed weight (with or without mucilage) of the two morphotypes was similar, a probable indication of similarity in food reserve in the seeds of the two morphotypes.

Table 1. Vigour assessment indices

Score	Interpretation
0	Sickly, and no sign of growth
1	Pale green and retarded growth
2	Pale green but no retarded growth
3	Greenish and growing healthily
4	Greenish, vigorously growing with broad leaves

There was a distinct variation in light intensity and temperature within each nursery throughout the study period (Fig. 1). As expected, the control (un-shaded frame) had the highest light intensity, while the nursery shaded with palm frond received the lowest amount of solar radiation. Similarly, temperature varied with nursery shade but the highest temperature was recorded in the colourless polyethylene shade, probably due to the greenhouse effect. Palm frond shaded nursery had the lowest temperature throughout the duration of the experiment.

The main effects of morphotypes on seedling emergence, quality of seedling in nursery, growth quality after hardening, and seedling growth parameters 12 weeks after transplanting (WAT) are shown in Table 4. The round morphotype seedling emergence quality traits were significantly ($P<0.05$) better than those of the oblong. Similarly, seedling growth qualities at thinning and one month after thinning were better in seedlings arising from the round morphotypes. Growth traits after hardening differed in some cases, but 12 WAT plant height, stem diameter and vigour index values were statistically similar. Number of leaves per plant was however, significantly ($P<0.05$) higher in round morphotype seedlings.

Table 3. Characterization of pawpaw fruits morphotypes used before experimentation

Characteristics	Pawpaw morphotypes	
	Oblong	Round
Fruit weight (kg)	2.0	1.8
Fruit length (cm)	33.0	27.0
Fruit thickness (cm)	3.0	4.5
Fruit diameter (cm)	11.0	16.0
Fruit circumference (cm):		
Widest point	38.5	47.5
Smallest point	29.0	44.0
100 fresh seed weight (g):		
With mucilage	11.9	12.6
Without mucilage	4.7	4.6
Fruit pulp colour	Orange	Red

Table 2. Some weather variables during the field experiment

Variables		Months			
		May	June	July	August
Temperature (°C)	max.	30.7	29.5	28.3	27.4
	min.	22.2	21.8	21.0	20.4
Light intensity (W m^{-2})	max.	658.0	784.4	675.0	645.5
	min.	4.3	4.7	3.8	5.3
Relative humidity (%)	10 h	76.7	78.9	79.4	79.7
	16 h	71.1	70.8	74.6	74.3
Rainfall (mm)		142.5	323.8	246.3	125.5
Number of rainy days		11	18	20	17

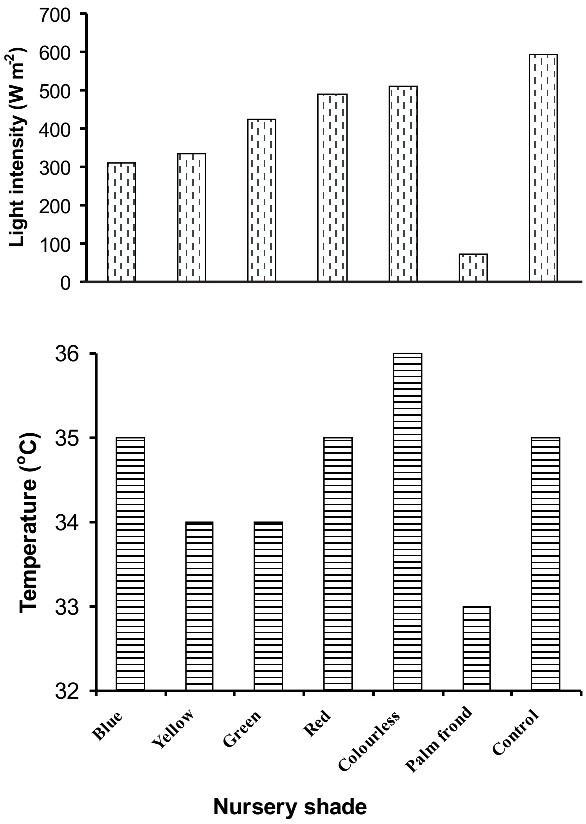

Fig. 1. Variation in light intensity and temperature in the different nursery shades.

Nursery shade significantly influenced most seedling emergence traits (Table 5). Days to first seedling emergence were similar, but days to 50% emergence and percentage emergence at first emergence varied with nursery shade cover colours. Time to 50% emergence was the earliest under red polyethylene cover and the longest under the yellow cover. Percentage seedling emergence at first emergence was the lowest (15%) under yellow polyethylene cover; the highest (25%) was recorded under colourless polyethylene. Trend in percent seedling emergence between the third and sixth week after seed sowing showed that emergence was consistently the highest under green polyethylene cover (Table 5) but was generally the lowest under yellow and red polyethylene covered nursery.

At thinning seedling height and vigour were significantly ($P<0.05$) influenced by different polyethylene colours used as nursery shade (Table 6). Seedlings grown under blue and green shades were the tallest compared to seedlings grown under palm frond shade and seedlings grown under non-shaded frame. Also, seedlings grown under green and colourless polyethylene shades and non-shaded control had similar numbers of leaves which were higher than those of seedlings grown under blue, red, yellow and palm frond shades.

Pawpaw seedlings grown under different nursery shades responded strongly to colour effects. There was progressive increase (over the initial growth at thinning) in seedling height, stem girths and vigour index one month after thinning. However, there was a slight decrease in number of leaves per plant except in palm frond shade (Table 6). Seedlings grown under green shade were taller.

The different nursery shade cover affected significantly ($P<0.05$) the growth pattern of pawpaw seedlings three weeks after hardening. There was an increase in seedling height, stem girth and vigour. It was observed that seedlings grown under green shade had the highest growth compared to those grown under palm frond (the traditional nursery shade). Fresh root, stem, and leaf weight and total dry matter weight of seedlings obtained from various nursery shades varied significantly (Table 6). Seedlings grown under green shade had the highest weight compared to other nursery shades.

Growth parameters of seedlings after field re-establishment were evaluated for three months (Table 7). Plants previously raised under green polyethylene were consistently taller and had wider stem girth during the first three months of re-establishment. Number of leaves and general plant vigour were in most cases similar during this period. Vigour indices for plants previously grown under green and red polyethylene shades were similar and higher than others.

Principal component analysis (PCA) of seedling emergence traits, growth parameters at thinning and after hardening is shown in Table 8. The three component axes retained revealed distinct trait contribution to the general variability in seedling growth. For each set of development traits, light intensity and temperature in the nursery shades accounted for a substantial percentage in the variability obtained. Light intensity and temperature variation in the different nursery types evaluated accounted for 40.3% of the variation in emergence in the entire nursery. Differences in nursery shade accounted for about 13% variation in number of days to 50% seedling emergence. PCA also revealed that 41% variability in seedling growth at thinning was due to the amount of light transmitted by the different polyethylene cover and temperature within each nursery. However, after hardening, variation in growth of seedlings was essentially (51%) explained by growth parameters measured, although light intensity and temperature accounted for about 30%. The combined effects of light intensity and temperature of previous nursery shade cover explained up to 40% of the differences obtained in photosynthetic efficiency after hardening.

DISCUSSION

The results of the study showed significant polyethylene colour effects on the seedlings emergence and growth of

T a b l e 4. The main effects of pawpaw morphotypes on emergence and seedling growth in the nursery after re-establishment in the field

Development phase/traits	Pawpaw morphotypes		$LSD_{0.05}$
	Round	Oblong	
Seedling emergence			
Days to first emergence	13.8	14.1	NS
Days to 50% emergence	17.8	18.4	NS
Percent emergence at first emergence	22.6	18.4	3.1
Percent emergence at: 3 WAP	69.4	47.8	5.8
4 WAP	72.8	51.4	5.6
5 WAP	74.4	52.6	5.5
6 WAP	75.4	55.6	5.3
Growth at thinning			
Seedling height (cm)	7.6	6.7	0.6
Number of leaves	9.6	8.7	NS
Vigour index	3.0	2.6	0.1
Growth one month after thinning			
Seedling height (cm)	11.9	10.4	1.2
Seedling stem diameter (cm)	0.6	0.5	0.1
Number of leaves	8.3	7.4	0.8
Vigour index	3.3	3.0	0.3
Growth after three weeks of hardening			
Seedling height (cm)	13.4	11.8	1.7
Seedling stem diameter (cm)	0.6	0.5	0.08
Number of leaves	7.0	6.0	NS
Vigour index	3.1	2.7	0.34
Total dry weight (g) of seedling	0.9	0.4	0.3
Growth 12 WAT			
Plant height (cm)	40.0	40.5	NS
Plant stem diameter (cm)	2.2	2.2	NS
Number of leaves	12.1	10.8	0.7
Vigour index	3.8	3.7	NS

WAP – weeks after planting, WAT – weeks after transplanting, NS – no significant.

T a b l e 5. The main effects of nursery shade colour on seedling emergence of two pawpaw morphotypes

Nursery shade cover colour	Days to		Percentage emergence				
	1st emergence	50% emergence	at 1st emergence	weeks after planting			
				3	4	5	6
Blue	13.8	18.0	18.0	60.0	65.3	68.7	71.3
Yellow	14.5	19.9	15.0	53.0	56.0	57.7	58.0
Green	13.6	18.6	22.3	66.0	69.7	71.3	72.0
Red	13.8	16.1	21.9	53.3	55.6	56.6	57.0
Colourless	14.0	18.5	25.0	64.7	68.3	70.0	70.0
Palm frond	14.5	18.3	19.2	58.3	62.0	62.0	62.7
Control (no cover)	13.4	17.3	22.0	55.0	57.7	58.0	60.0
$LSD_{0.05}$	NS	2.5	5.8	10.8	10.4	10.2	10.0

T a b l e 6. The main effect of nursery shade cover on growth characteristics of two pawpaw morphotypes at thinning, one month after thinning, and three weeks after hardening

Nursery shade cover colour	Growth														
	at thinning			one month after thinning				after three weeks of hardening							
	Ht (cm)	NL	VG	Ht (cm)	Sd (cm)	NL	VG	Ht (cm)	Sd (cm)	NL	VG	FWR (g)	FWS (g)	FWL (g)	TDW (g)
Blue	8.0	7.5	2.9	11.5	0.4	6.1	2.8	12.1	0.4	4.0	3.0	2.9	1.5	0.1	0.2
Yellow	6.8	6.4	2.8	9.7	0.4	6.2	2.8	10.8	0.4	6.0	3.0	1.1	1.0	0.4	0.2
Green	8.0	10.1	2.8	14.7	0.6	9.2	3.8	17.9	0.7	7.0	4.0	16.5	5.8	3.0	2.2
Red	7.2	9.6	2.7	10.7	0.5	6.9	2.9	11.6	0.6	6.0	3.0	1.3	1.0	0.4	0.2
Colourless	7.2	10.4	2.8	10.2	0.5	6.9	3.0	10.9	0.6	5.0	3.0	1.8	1.1	0.3	0.2
Palm frond	6.7	9.9	2.7	10.8	0.5	10.1	3.4	13.0	0.6	8.0	3.0	5.0	2.2	1.5	0.7
Control	6.4	10.3	2.8	10.2	0.4	9.2	3.3	11.8	0.5	7.0	3.0	6.6	2.7	1.8	0.9
$LSD_{0.05}$	1.2	2.0	0.1	0.8	0.1	1.6	0.5	3.0	0.1	1.5	0.6	4.1	1.8	0.9	0.6

Ht – height, NL – number of leaves, VG – vigour index, Sd – stem diameter, FWR – fresh weight of root, FWS – fresh weight of stem, FWL – fresh weight of leaf, TDW – total dry weight.

T a b l e 7. The main effect of nursery shade cover on growth pattern of two pawpaw morphotypes during the first 12 weeks of re-establishment in the field.

Nursery shade cover colour	4 WAT				8 WAT				12 WAT			
	Ht (cm)	Sd (cm)	NL	VG	Ht (cm)	Sd (cm)	NL	VG	Ht (cm)	Sd (cm)	NL	VG
Blue	27.2	1.28	11.9	3.6	32.2	1.85	14.9	3.7	38.8	2.05	12.2	3.8
Yellow	25.8	1.33	12.6	3.8	37.2	1.93	15.1	3.8	39.6	2.13	11.8	3.8
Green	33.0	1.69	12.6	3.9	42.9	2.20	13.9	3.8	47.0	2.61	11.2	3.9
Red	30.0	1.52	12.8	3.9	40.5	2.12	14.8	3.8	44.4	2.36	11.9	3.9
Colourless	24.3	1.45	13.3	3.8	34.0	1.89	15.3	3.6	37.2	2.04	11.9	3.6
Palm frond	24.7	1.36	11.8	3.5	31.7	1.83	13.8	3.4	35.1	2.02	10.3	3.5
Control	26.3	1.36	12.9	3.8	36.9	1.89	14.5	3.7	39.4	2.06	10.9	3.7
$LSD_{0.05}$	5.6	0.25	NS	NS	4.6	0.25	NS	NS	5.3	0.33	1.2	NS

Explanations as in Tables 4 and 6, NS – no significant.

differences in light quality transmitted by the polyethylene colours and temperature variation within each nursery shade. A plant's response to light will vary depending on the intensity and wavelength of the light it receives.

Although the different polyethylene colours were utilized as nursery cover in this study, Orzolek and Murphy (1993), and Decoteau *et al.* (1989) reported that polyethylene colours used as mulches have distinct optical characteristics and thus reflect different radiation patterns into the canopy of a crop, thereby affecting plant growth and development. Thus, variable light transmitted by the different shade colours in this study coupled with distinct temperature variation in each shade colour would explain the differences in seedling quality obtained. The immediate micro-environment in which seedlings are grown has been shown to have a major role in growth and development of crops (Baiyeri, 1992). There were also carryover effects of the previous nursery shade on the growth quality of the test crops during the first three months of re-establishment. Crop growth rate at any instant time is related to its earlier biomass; therefore, seedlings that had accumulated higher biomass (dry matter) at the nursery stage, relative to those with poorer photosynthetic efficiency, would ordinarily grow faster when re-established in the field. Therefore, better field growth of seedlings previously raised under the green nursery shade than seedlings from the other nursery shades was in consonance with earlier study of Baiyeri and Ndubizu, (1994), which demonstrated that quality of seedlings transplanted influenced their re-establishment in an orchard, and, consequently, the future productivity of the orchard. The green polyethylene nursery shade enhanced the highest percentage emergence and the best seedling quality in nursery and after re-establishment in the field, probably because green polyethylene has the best blend of

T a b l e 8. Principal component analysis of emergence quality traits, seedling traits at thinning and after hardening, showing latent vector loadings

Development phase/traits	PRIN 1	PRIN 2	PRIN 3
Seedling emergence			
Days to 50% emergence	0.3489	0.3684	**0.8608**
Percent emergence: 3 WAP	**0.6533**	-0.1528	-0.1936
Percent emergence: 6 WAP	**0.6585**	-0.1492	-0.2007
Light intensity in nursery	-0.1323	**-0.6528**	-0.2390
Temperature in nursery	0.0205	**-0.6265**	-0.3523
Percent variation explained	**41.5**	**40.3**	**12.8**
Seedling quality at thinning			
Height	-0.2879	-0.4474	**-0.7556**
Number of leaves	-0.0496	**0.6150**	**-0.6000**
Vigour index	-0.4538	-0.4998	0.1263
Light intensity in nursery	**-0.6303**	0.1897	0.1381
Temperature in nursery	**-0.5580**	0.3684	0.1844
Percent variation explained	**41.0**	**33.8**	**15.9**
Seedling quality after hardening			
Height	**-0.5081**	-0.2323	0.3592
Stem diameter	-0.4055	-0.3314	-0.4023
Number of leaves	-0.4205	0.2140	**-0.6708**
Vigour index	**-0.4540**	-0.3601	0.3888
Light intensity in nursery	0.1913	**-0.6258**	-0.3229
Temperature in nursery	0.3976	**-0.5188**	-0.0609
Percent variation explained	**51.0**	**29.9**	**12.2**
Photosynthetic yield after hardening			
Total fresh weight	**-0.5922**	-0.3490	0.2398
Total dry weight	**-0.5953**	-0.3470	0.0831
Light intensity in nursery	0.2389	**-0.7145**	**-0.6537**
Temperature in nursery	0.4876	-0.4974	**0.7129**
Percent variation explained	**56.8**	**40.0**	**3.1**

WAP – weeks after planting.

the light quality and temperature regime needed by the test crop. Decoteau *et al.* (1989) reported that the colour of plastic mulch largely determines its energy-radiating behaviour and its influence on the microclimate around a vegetable plant. Thus, green polyethylene could have probably ensured the optimum microclimate for germination and seedling growth in the study area.

The PCA results explained the physiological modulations by the different nursery shade on seedling quality via light quality and temperature. These two variables explained 40, 41, 30 and 40%, respectively, of the variability in seedling emergence, seedling quality at thinning and after hardening, and seedling photosynthetic yield. This translates to mean that, to a very large extent, variable seedlings quality obtained was due to variable light quality and temperature range under the different nursery shades.

The differences between morphotypes with respect to seedling emergence and general growth performance are probably due to differences in their genetic make-up.

CONCLUSIONS

1. Principal component analysis revealed that differences in morphological and physiological quality of seedlings produced under the seven nursery shades evaluated were essentially due to differences in light quality and temperature regimes under the shades (other environmental variables that could influence plant growth were similar).

2. The two pawpaw morphotypes showed some specific pattern of response to the different nursery shade colours evaluated. Seedling quality of the two morphotypes was significantly higher when grown under green polyethylene nursery shade than others.

3. Palm frond is probably the oldest nursery shade used in tropical Africa and colourless polyethylene is also a widely used shade for most nursery seedlings but they were not found to be the best for the test crop. Thus, this study has shown that green polyethylene colour is the most appropriate nursery shade (at least for the test crop) for raising high quality seedlings under Nigeria sub-humid environment.

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