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Original Research Paper

Morpho-physiological changes in oil palm (*Elaeis guineensis* Jacq.) tenera hybrid seedlings raised under different shade levels

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ABSTRACT

Climatic conditions prevailing in oil palm growing states of India indicate the need for shade during primary stage of oil palm nursery for optimum growth and vigour of seedlings. Experiments were conducted to standardize the shade requirement based on growth/quality of oil palm seedlings in summer, rainy and winter seasons by providing 25%, 50% and 75% ultra violet stabilized high density poly ethylene (HDPE) shade nets. Results were found significant among the treatments for most of the growth parameters studied over the seasons. Higher growth for key characters like seedling height, leaf area, collar girth and dry matter production were recorded at 75% shade level. Similarly, higher chlorophyll content, photosynthetic rate, transpiration rate, stomatal conductance and inter cellular CO_2 concentration were observed at 75% shade. Among the season, seedling growth was vigorous in rainy season followed by summer and winter seasons. Hence, provision of 75% shade found to be ideal for raising seedlings during primary stage of nursery in oil palm.

Keywords: Growth, oil palm, seedling and shade

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is the highest edible oil yielding crop and perennial in nature with 30 years productive life. It is a fast-growing plantation cum oil seed crop with an area of 4.00 lakh ha under cultivation in India (Anonymous, 2022) and there is a lot of demand for planting material in the country. Production of high-quality planting material is of prime importance for establishing productive oil palm plantations in the country. Oil palm is mainly propagated by seedlings which are raised in poly bags round the year in double stage nursery system *i.e.* primary nursery for 4 months under shade net and secondary nursery for 8 months in open conditions. Frequent modification in shade net house as per the seasons is not possible as the shade net houses/pandals are semi-permanent structures. Oil palm is grown in diversified agro-climatic zones of India and these are different from traditional oil palm countries like Indonesia and Malaysia. Temperature and sun light decide the quality of seedlings during nursery stage in oil palm. Harsh climatic conditions particularly high temperature (38-45ºC) and light intensity during summer are detrimental to the growth of oil palm seedlings. So, shading is must for getting good growth in oil palm seedlings in primary nursery stage. Shade net reduces both light and heat intensity and this modified environment/microclimate can protect seedlings from heat stress and promote plant growth. Shading promotes the vigour and growth of seedlings in oil palm (Samuel et al., 2017). But the information on level of shade requirement for primary nursery and its impact over seedling growth is not available and this information is very much required for oil palm nursery growers in India. Hence, series of experiments were conducted to standardize the optimum shade level and quantify its effect on growth and development of oil palm seedlings during primary nursery stage in summer, rainy and winter seasons.

MATERIALS AND METHODS

The studies were conducted at ICAR-Indian Institute of Oil Palm Research, Pedavegi, West Godavari district, Andhra Pradesh during 2020-21. Experimental site is located at 16º 43 N′ and 81º 09’ E′ with 13.41 meter above mean sea level. The location Pedavegi experiences hot and humid weather owing to proximity to the sea Bay of Bengal. Average annual temperature ranges from 21.8 ºC to 34.8 ºC, relative humidity 69.3 per cent and average rainfall 1215 mm/annum. Weather parameters recorded during the study period are furnished in Fig. 1, 2 & 3.

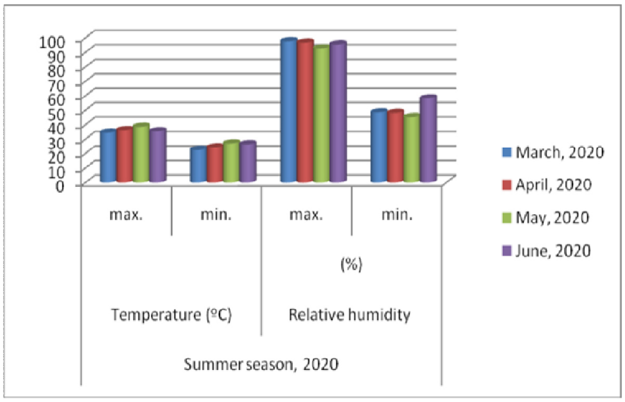

Fig. 1 : Weather conditions prevailed during the summer season at ICAR-IIOPR, Pedavegi, Andhra Pradesh

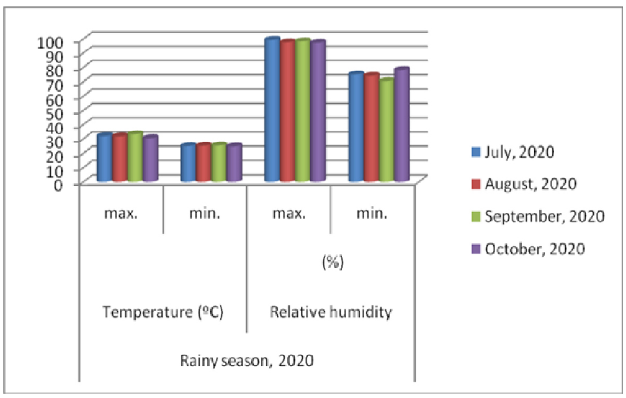

Fig. 2 : Weather conditions prevailed during the rainy season at ICAR-IIOPR, Pedavegi, Andhra Pradesh

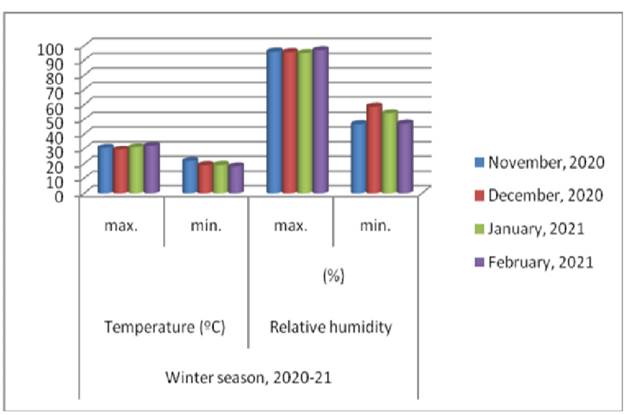

Fig. 3 : Weather conditions prevailed during the winter season at ICAR-IIOPR, Pedavegi, Andhra Pradesh

Experiment was laid out in completely randomized design (CRD) factorial with 4 treatments and 5 replications with 20 seedlings in each replication. Village base silt and farmyard manure mixed in 2:1 (v/v) ratio were used as a growing medium. Seedlings were raised at four shade levels *i.e.* 25%, 50%, 75% and no shade (open condition) and in three seasons *i.e.* summer (March-June), rainy (July-October) and winter (November-February). Uniform and healthy seed sprouts of oil palm hybrid *Tenera* (670 *Dura* x 77 *Pisifera*) produced from Oil Palm Seed Garden, Pedavegi, Andhra Pradesh were used for the study. Shade net house/pandal with 2 m x 2 m dimensions were erected with cement concrete poles covered with UV stabilized high density poly ethylene (HDPE) green colour agro shade net (25%, 50% and 75%) on all four sides. Seedlings were grown in poly bags (size 23 cm x 15 cm) by following the recommended nursery practices (Rethinam and Murugesan, 2000) in all the treatments uniformly during the study period in all the seasons.

Vegetative growth of oil palm seedlings was determined by measuring plant height, leaf and root production, leaf area, collar girth, fresh and dry biomass on four-month-old seedlings. Chlorophyll and carotenoids contents were estimated by UV-VIS spectrophotometer (*Shimadzu UV-1800*) by following dimethyl sulfoxide (DMSO) method. Gas exchange parameters *i.e.* photosynthetic rate (P_N), transpiration rate (E), stomatal conductance (gs), intercellular CO_2 (ci) and leaf temperature (T_L) were recorded on 4-month-old seedlings by using portable photosynthesis apparatus (*LCA-4, ADC*, Hertfordshire, UK) connected to a *PLC 4* chamber between 9.00-11.00 hrs. Fully opened leaf *i.e.*, 3rd leaf from the top of seedlings was used for measurements. For comparing shade effect over different seasons, combined analysis was carried out using proc generalized linear model (GLM) procedure SAS version 9.3. Post-hoc analysis was conducted using least significant difference (LSD) and effects were considered as significant at $p<0.05$.

RESULTS AND DISCUSSION

Most of the morphological and physiological responses of oil palm seedlings differed significantly among the shade levels, seasons and between shade levels and seasons. Mean height of oil palm seedlings was significantly high during rainy season (41.86 cm) compared to summer (34.22 cm) and winter seasons (22.88 cm) (Table 1). Significantly taller seedlings were observed at 75% shade (37.40 cm), whereas, the shorter ones were recorded in no shade (28.13 cm). Similarly, seedlings grown under 75% shade during rainy season (45.50 cm) were taller compared to seedlings in other treatments except at 75% shade

Table 1 : Influence of shade on growth parameters of oil palm seedlings raised in different seasons

Treatment	Seedling height (cm)				Leaves/seedling				Leaf area (cm²)			
	summer	rainy	winter	mean	summer	rainy	winter	mean	summer	rainy	winter	mean
25% shade	32.26	41.26	25.06	32.86	5.20	6.60	4.20	5.33	413.84	1004.20	237.37	551.80
50% shade	35.38	42.00	23.28	33.55	5.40	6.60	4.00	5.33	445.07	1132.80	176.69	584.86
75% shade	43.30	45.50	23.40	37.40	5.60	6.40	4.20	5.40	660.16	1101.97	213.07	658.40
No shade	25.94	38.70	19.76	28.13	5.00	6.60	4.20	5.27	291.10	969.812	187.66	482.86
Mean	34.22	41.86	22.88		5.30	6.55	4.15		452.55	1052.20	203.70	
LSD (P=0.05)												
Season				1.84				0.24				78.72
Shade				2.13				NS				90.90
Season x Shade				3.69				0.48				157.43

during summer season. Similarly, taller seedlings were observed under shade in oil palm nursery (Samuel et al., 2017). Present results clearly indicate the increasing trend in seedling height as the shade density increased in summer and rainy seasons. Seedling growth was vigorous in rainy season, medium in summer and slow during winter season. Seedling height was poor in all the seasons at no shade (open condition). Oil palm is basically a tropical plant which needs warm and humid conditions normally present during rainy season and because of this, better seedling height was observed in rainy season.

The results revealed that shade densities over the seasons could not influence the leaf production (Table 1) as also reported by Samuel et al. (2017) in oil palm. Seedlings grown in rainy season (6.55) possessed highest number of leaves as compared to summer (5.30) and winter seasons (4.15). Mean leaf production was significantly higher at all the shade levels during rainy season when compared to summer and winter seasons. This may be attributed to optimum weather conditions like warm and humid conditions prevailed during rainy season.

There were significant variations among the seasons and shade levels for leaf area of seedlings (Table 1). Mean leaf area in rainy season was recorded significantly high (1052.20 cm^2) compared to summer (452.55 cm^2) and winter (203.70 cm^2) seasons. Among the shade levels, maximum leaf area was estimated with 75% shade (658.40 cm^2) which was markedly superior to rest of the treatments but it was at a par with 50% shade level. Similarly, enhanced leaf area in tomato seedlings was reported under shading (Formisano et al., 2022). Mean leaf area was recorded maximum at 50% shade level (1132.80 cm^2) during rainy season and it was on par with other shade levels during rainy season.

Among the seasons, collar girth (6.91 cm) was significantly better in seedlings raised in rainy months (Table 2). There was no impact of shade levels over the collar girth. However, relatively more collar girth (5.24 cm) was recorded under 25% shade level. Seedlings with maximum collar girth were recorded in no shade (7.20 cm) and closely followed by 25% shade level (7.06 cm) in rainy season. It reflected the ability of seedlings to store more quantity of photosynthates in stem which in turn might have happened due to higher photosynthetic rate and better utilization of nutrients (Hastuti 2021).

Table 2 : Influence of shade on growth parameters of oil palm seedlings raised in different seasons

Treatment	Collar girth (cm)				No. of primary roots/seedling				Primary root length (cm)			
	summer	rainy	Winter	mean	summer	rainy	winter	mean	summer	rainy	winter	mean
25% shade	5.14	7.06	3.64	5.24	4.20	5.80	2.80	4.27	32.42	39.44	36.28	36.05
50% shade	4.78	6.60	3.56	4.98	4.60	5.20	2.80	4.20	35.72	36.32	25.52	32.52
75% shade	5.00	6.76	3.44	5.07	4.60	5.60	3.20	4.47	36.86	35.82	27.18	33.29
No shade	4.24	7.20	3.60	5.01	4.00	5.40	2.60	4.00	27.48	34.63	38.76	33.62
Mean	4.79	6.91	3.56		4.35	5.50	2.85		33.12	36.55	31.93	
LSD (P=0.05)												
Season				0.24				0.41				3.85
Shade				NS				NS				NS
Season x Shade				0.47				0.81				7.70

There were no marked differences among the treatments in production of primary roots in all the seasons (Table 2). This indicates that root production was not influenced by shade levels. Significantly higher mean root count was recorded in rainy season (5.50) as compared to summer (4.35) and winter (2.85) seasons. The highest mean root production was observed at 25% (5.80) in rainy season and the differences among shade levels were on par with one another. Poor root production was observed in seedlings grown in winter season at all the shade levels. Samuel et al. (2017) obtained similar results in oil palm. Results were found non-significant among the treatments (Table 2) showing no influence of shade levels over the root length. Primary roots were lengthier in rainy season (36.55 cm) which is markedly higher than summer (33.12 cm) and winter (31.93 cm) seasons. Results for mean root length between summer and winter seasons were at par with each other. Seedlings with longer roots were observed in rainy season at 25% shade level (39.44 cm).

Mean shoot dry weight recorded at 75% shade level (4.76 g) was significantly higher as compared to seedlings raised in open (3.75 g) but not significant with other shade treatments (Table 3). Maximum mean shoot dry weight was recorded in rainy season (8.07 g) which was markedly higher than other seasons. Better shoot dry weight was observed at 75% (8.53 g) and 50% (8.53 g) shade levels during the rainy season and both were significantly superior to rest of the treatments. Though there were significant differences among the seasons (Table 4) for mean root dry weight but the results were not significant among the treatments for mean root dry weight. Rainy season recorded the maximum mean root dry weight (1.85 g) and it was significantly higher than summer (1.10 g) and winter (0.44 g) seasons. Shade level 75% recorded the maximum root dry weight (2.04 g) in rainy season while it was the minimum (0.32 g) at 75% shade level during winter season. Mean root: shoot ratio (Table 3) was significantly higher in summer season (0.34), while, it was lower in rainy season (0.23). Of all the treatments, higher root: shoot ratio was observed in open (0.30) and 25% shade level (0.30), whereas, the lower root: shoot ratio was recorded under 75% shade level (0.25). Khan et al. (2000) also reported similar results in conifer

Table 3 : Influence of shade on biomass of oil palm seedlings raised in different seasons

Treatment	Shoot dry weight (g)				Root dry weight (g)				Root : shoot			
	summer	rainy	winter	mean	summer	rainy	winter	mean	summer	rainy	winter	mean
25% shade	3.30	7.85	1.71	4.29	1.25	1.79	0.51	1.19	0.38	0.23	0.29	0.30
50% shade	3.24	8.53	1.38	4.39	1.17	1.60	0.43	1.07	0.36	0.19	0.31	0.29
75% shade	4.31	8.53	1.43	4.76	1.19	2.04	0.32	1.18	0.28	0.24	0.23	0.25
No shade	2.29	7.37	1.60	3.75	0.77	1.96	0.50	1.08	0.33	0.27	0.28	0.30
Mean	3.29	8.07	1.53		1.10	1.85	0.44		0.34	0.23	0.28	
LSD (P=0.05)												
Season				0.47				0.12				0.03
Shade				0.55				NS				0.03
Season x Shade				0.95				0.25				0.05

species seedlings. Maximum root: shoot ratio at 25% shade level (0.38) was recorded during summer season, whereas, the minimum was noticed at 50% shade level in rainy season (0.19). Harsh weather conditions (Fig. 1) might have promoted the root growth rather than shoot growth during summer. Weather conditions prevailed during rainy season promoted the shoot growth at the expense of root growth. Higher root: shoot ratio during summer season may be because of proper distribution of photosynthates to root portion (Seman et al., 2018).

The treatment 75% shade level recorded the maximum mean fresh (21.54 g) and dry (6.06 g) biomass, whereas, the minimum levels (16.02 g and 4.63 g) were quantified in seedlings grown in no shade condition (Fig. 4 & Fig. 5). Among the seasons, seedlings produced significantly higher mean fresh (33.16 g) and dry biomass (9.87 g) during rainy season and this must be due to vigorous growth of seedlings owing to congenial/ favourable weather conditions prevailed during rainy season. Lower mean fresh (6.81 g) and dry biomass (1.66 g) production was observed in winter season at 75% shade level. Better fresh and dry biomass was estimated in seedlings grown in rainy season (37.88 g and 10.86 g) at 75% shade level. Enhanced biomass production at 75% shade level must be attributed to better seedling vigour in terms of seedling height, leaf area, collar girth and net photosynthetic rate of seedlings. Similarly, maximum total biomass was recorded under 75% shade in *Pongamia pinnata* seedlings (Sankeshwar, 2009). Biomass production was increased with decreasing light intensity probably due to enhanced biomass distribution in *Greenwayodendron suaveolens* (Olajuyigbe & Akhande, 2015). Relatively, high biomass production was observed in all the treatments in rainy season, medium in summer season and least in winter season. Better fresh and dry matter production of seedlings grown under shade reflects the compulsory need for shade particularly in summer season and to some extent in rainy season. However, seedling growth was better in no shade (open condition) as compared with shading due to moderate/mild weather conditions prevailed during winter season (Fig. 3).

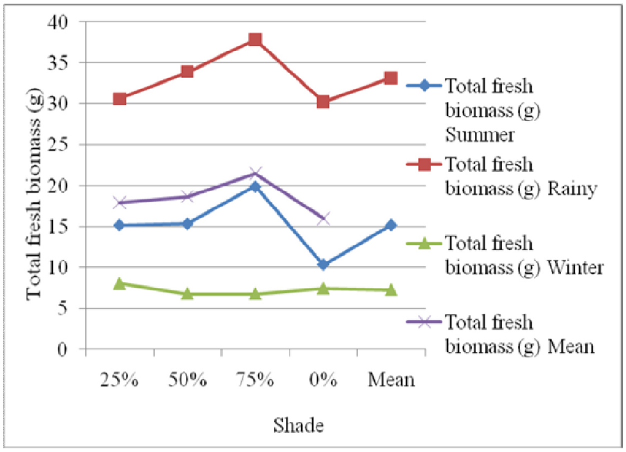

Fig. 4 : Influence of shade on total fresh biomass of oil palm seedlings raised in different seasons

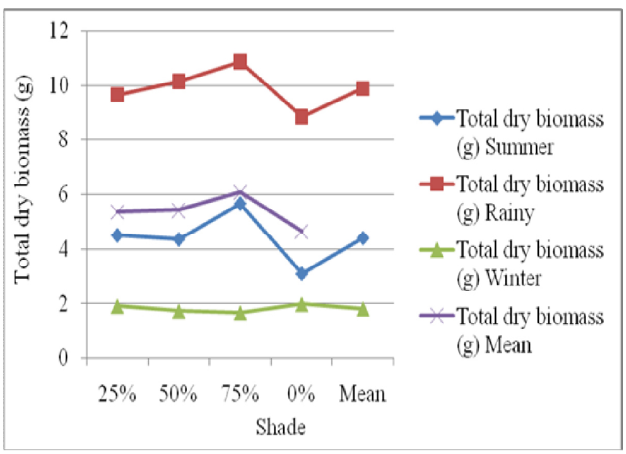

Fig. 5 : Influence of shade on total dry biomass of oil palm seedlings raised in different seasons

Overall, growth of the seedlings was quite vigorous during the rainy season and it was significantly better than summer and winter seasons. Prevalence of favourable weather conditions (Fig. 2) in rainy season might have promoted the growth and development. Being a tropical crop, oil palm needs minimum temperature of 22-24°C for its optimum growth and development (Corley & Tinker, 2016). Poor growth of seedlings during winter might be due to prevalence of cool weather with below 20°C temperature during night times (Fig. 3). Growth of the seedlings in summer was significantly lesser than rainy season but higher than winter season. Harsh weather conditions (Fig. 1) in summer certainly suppressed the growth of the seedlings though sufficient moisture was maintained in growing medium. Among different shade levels, vigorous growth and development of seedlings over the seasons was observed at 75% shade which reflects the dire need for shade during the primary stage of nursery in oil palm. Similarly, 75% shade was found to be ideal for raising *Terminalia arjuna* seedlings in nursery (Prasad, 2002).

Chlorophyll and carotenoids play a vital role in light reactions of photosynthesis and photosynthetic electron transport system in plants (Gardener et al., 2010). Chlorophyll and carotenoid contents were higher in seedlings raised under shade as compared with open condition (Table 4). High light intensity in open condition decreased chlorophyll and carotenoids contents. The treatment 75% shade (3.86 mg g^{-1}) followed by 50% shade (3.86 mg g^{-1}) recorded significantly higher chlorophyll content in leaves when compared with no shade (3.18 mg g^{-1}). Similar trend was observed among the treatments for carotenoid content in leaves. Results were at par between no shade (3.18 mg g^{-1} & 1.04 mg g^{-1}) and 25% shade level (3.50 mg g^{-1} & 1.15 mg g^{-1}) for chlorophyll and carotenoids contents, respectively. Higher concentration of chlorophyll at 75% and 50% shade levels reflects the necessity of shade during summer and present results indicate existence of direct relationship between chlorophyll content and photosynthetic rate (Suresh and Nagamani 2006). Higher chlorophyll level was recorded in naval orange (Incesu et al., 2016) and tomato seedlings (Formisano et al., 2022) under shading.

Gas exchange characters like photosynthetic rate, transpiration rate, stomatal conductance, inter cellular CO_2 level and leaf temperature were found significant among the treatments (Table 4). Maximum values for photosynthetic rate and transpiration rate, stomatal conductance and intercellular CO_2 level were recorded under 75% shade which was significantly superior to other treatments. Whereas, minimum values for the above parameters were observed in no shade (open condition). Increasing trend was observed for above gas exchange parameters as the shade level increased from 25% to 75%. Leaf temperature was significantly lower under shading as compared with open condition. Leaf temperature reduced progressively as the degree of shading was increased from 25 to 75% which reduced the photosynthetic rate and associated parameters (Suresh and Nagamani 2006).

Table 4 : Influence of shade on gas exchange parameters of oil palm seedlings raised in summer season

Treatment	Total chlorophyll content (mg g^{-1})	Carotenoids (mg g^{-1})	Photosynthetic rate (µmol m^{-2} s^{-1})	Transpiration rate (mmol m^{-2}s^{-1})	Stomatal conductance (mmol m^{-2} s^{-1})	Inter cellular CO_2 concentration (ppm)	Leaf temperature (°C)
25% shade	3.50	1.15	3.34	2.48	0.030	211.08	27.25
50% shade	3.86	1.24	3.86	2.75	0.040	226.15	26.55
75% shade	3.86	1.27	4.48	3.05	0.058	262.09	25.16
No shade	3.18	1.01	2.80	2.55	0.036	242.01	33.71
LSD (P=0.05)	0.48	0.11	0.37	0.21	0.010	23.74	0.72

Higher gas exchange measurements at 75% shade reflect the light saturation of seedlings at 75% shade. Higher photosynthetic rate at 75% shade might be attributed to higher CO_2 level and relative humidity inside shade net house when compared with open condition. Lower levels of gas exchange parameters in no shade (open condition) might be due to higher temperature in open condition which in turn might have reduced photosynthetic rate and transpiration rate by closing the stomata in leaves of oil palm seedlings. Higher photosynthetic rate is directly correlated with main growth indicators *viz*., seedling height, collar girth, leaf area and dry matter content. Better growth of seedlings under deep shade indicates morpho-physiological adaptation of oil palm seedlings to the shade. The growth of oil palm seedlings under shade might be due to better stomatal control under partial shade conditions which increased the growth parameters due to higher photosynthetic rate (Suresh and Nagamani 2006). Similar observations were made at 75% shade intensity in oil palm (Osama, 2003) and 50% shade in drumstick (Lamia et al., 2014).

CONCLUSION

The present study revealed that shade exerted significant influence on growth and vigour of oil palm seedlings at primary nursery stage. Findings demonstrated that shading is must for better growth and development of oil palm seedlings particularly during summer and to some extent in rainy season. Better results for main parameters such as seedling height, leaf area, collar girth and dry matter production were observed at 75% shade level. Therefore, 75% shade net can be an optimum shade level for raising seedlings during primary stage of oil palm nursery.

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