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The Effects of Shading Regimes on the Growth of Cocoa Seedlings (*Theobroma cacao* L.)

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RINGKASAN

Satu percubaan telah dijalankan untuk mengkaji pengaruh teduhan; 80, 55, 30 dan 0 peratus, iaitu tidak berteduhan, ke atas tumbesaran anak benih koko dalam masa lima bulan di dalam tapak semaian. Keputusan menunjukkan bahawa keadaan teduhan sebanyak 80 peratus dalam masa tiga bulan yang pertama adalah optima untuk tumbesaran maksimum. Bagi koko yang berumur tiga bulan ke atas, nilai teduhan optima menurun kepada 55 peratus. Interaksi di antara umur tumbuhan dan keadaan teduhan adalah disebabkan oleh perubahan kepada purata kadar asimilasi bersih sebagaimana dipengaruhi oleh teduhan di antara daun itu sendiri di dalam proses pertumbuhan dan juga kesan keamatan cahaya terhadap kadar pengeluaran daun. Keadaan yang tidak berteduhan langsung adalah merosakkan tanaman; oleh itu amalan pemberian teduhan mestilah mengambil kira imbangan di antara keupayaan tumbuhan untuk mengeluarkan daun dan keupayaan untuk pencernaan.

SUMMARY

An experiment was conducted to study the effects of different shading regimes: 80, 55, 30 and 0 percent i.e. full sunlight on the growth of cocoa seedlings during the first five months in the nursery. It was observed that the shading regime for optimal dryweight accumulation was under 80 percent shade during the first three months gradually reducing to 55 percent shade from the fourth month onwards. This interaction between age and shading regime was brought about by changes in net assimilation rates in response to self shading as the plant aged and also to the effects of lead production in response to different light intensities. Totally unshaded condition was detrimental to plant growth. Shading practice has to take into account the balance between capacity for leaf production and optimal capacity for assimilation.

INTRODUCTION

The subject of light and shade requirements of the cocoa plant has been extensively reviewed by Alvim (1965), Bonaparte (1967), Olanniran (1977) and recently brought up to date by Owusu (1978). These reviews pointed out the need for some degree of shade in the establishment of the cocoa plant. Early work by Evans and Murray (1953) indicated an optimal light intensity of 50 percent full sunlight for 12–18 month old plants. In a guide to nursery practice, Sheperd (1976) recommended a light regime of 20 percent full sunlight (80 percent shade) during the first two months of growth with the light gradually increasing (decreasing shade) to match the final shade conditions in the field.

This study seeks to determine the shade requirements at different growth stages of cocoa seedlings for optimum growth and development during the nursery stage of up to five months.

MATERIALS AND METHODS

Uniform sized seeds of clone PBC 106 (upper Amazon hybrid, not on recommended list) supplied by the Prang Besar Estate were germinated in polybags, measuring 20 cm x 30 cm layflat, containing soil mixture of the ratio 7:3:3 (soil : sand : organic matter). Basal compound fertilizer of 12:12:17:2 (N:P:K:Mg) was supplied at 10 g/bag and lime was added to bring the pH to 6.3. Seeds were allowed to germinate during the

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first month under 85% shade; seedlings of even size were later selected for treatments.

Treatments and Maintenance

Shading treatments consisted of the following (i) the unshaded control which corresponds to a light intensity of 200 μ ES^{-1} m^{-2} on a bright day as measured by a LI-COR quantum sensor (ii) one layer of 1 mm-mesh nylon netting (30% shade) (iii) two layers of nylon netting (55% shade) and (iv) a combination of two layers of nylon netting and 2.5 cm wooden plants spaced at 2.5 cm apart (80% shade). This experiment was conducted in the Agronomy Research Area at Universiti Pertanian Malaysia.

Prior to shading treatments, seedlings were gradually exposed to decreasing shade conditions for a period of two weeks to adapt to the final conditions of the treatments. The design of the experiment consisted of four shading regimes x 3 replications x 4 harvests arranged in a split plot design with shade as the main plot giving a total of 12 plants per harvest.

Fertilizer application corresponded to that recommended by Sheperd (1976) for nursery plants. Pest control consisted of snail bait and weekly spraying of Bidrin and Difolatan at the recommended rates. The plants were watered at least once a day to ensure an ample supply of water. Under the various shading regimes plants were spaced at 30 cm x 35 cm apart.

Harvests

Harvests were carried out at the end of the second, third, fourth and fifth months after germination. At each harvest, lead area, total plant dry weight and plant height were measured from the cotyledon scar to the shoot apex. The data obtained were statistically analysed. Calculations of net assimilation rates, leaf area ratios and relative growth rates according to the conventional methods (Gregory, 1917) were carried out using the mean values for total plant dry weight, leaf dry weight and leaf area.

RESULTS

Cocoa seedlings under the various shading regimes gradually increased in height *(Fig. 1)* during the five months in the nursery. Plants under 55 percent and 30 percent shade were significantly ($P<0.05$) taller than those under 80 percent shade or 0 shade (full sunlight at the third, fourth and fifth month). Differences at the second months were not significant (harvest x shade interaction signification at $P>0.05$). Plants under 80 percent

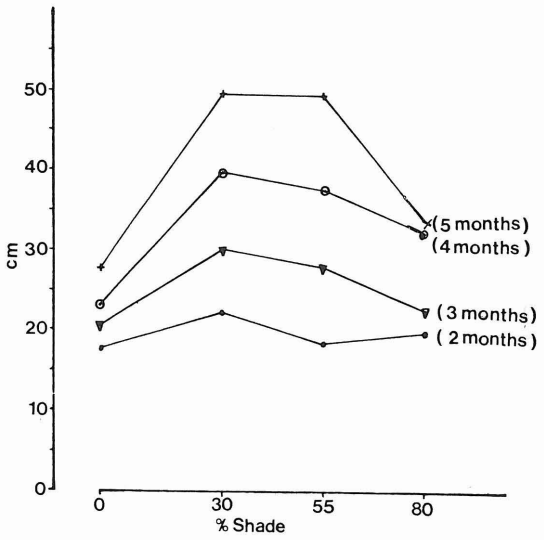

Fig. 1. Plant height.

$LSD_{p=0.05}$ *shade means* = *7.84*

$LSD_{p=0.05}$ *harvest means* = *4.49*

$LSD_{p=0.05}$ *shade harvest* = *7.79*

shade did not show signs of etiolation whereas those under full sunlight were stunted, with an overall appearance of poor growth.

For plants under 'O' shade (i.e. full sunlight) total leaf area per plant *(Fig. 2)* increased very

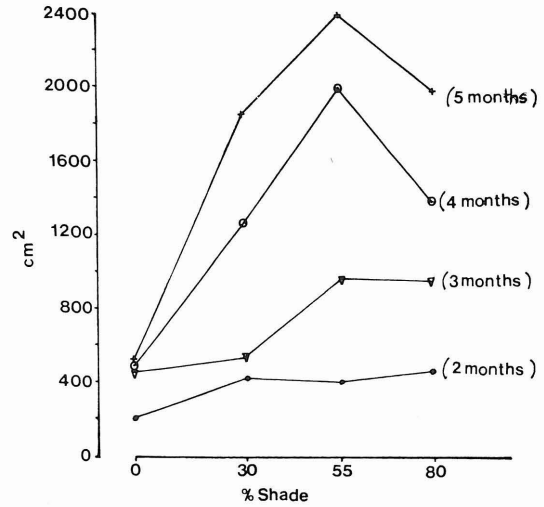

Fig. 2. Leaf area per plant.

$LSD_{p=0.05}$ *shade means* = *340.0*

$LSD_{p=0.05}$ *harvest means* = *292.9*

$LSD_{p=0.05}$ *shade harvest* = *507.3*

slowly during the five months; the size of individual leaves and total leaf area from these plants were significantly ($P<0.01$) smaller than those under shaded conditions. They showed signs of scorching and exhibited mineral deficiency symptoms. A very significant ($P<0.01$) interaction between shading regime and plant age in regard to leaf area showed that the highest leaf areas were obtained at 55 percent and 80 percent shade during the first three months of growth, whereas at the fourth and fifth months, optimal shade was at 55 percent.

A similar significant ($P<0.01$) interaction between age and shading regime in respect to total plant dryweight was also observed *(Fig. 3)*. For the first three months of growth the highest total dry matter was obtained under 80% shade, which decreased with further reduction of shade. At the age of four months, optimum plant dry matter was obtained under 80 percent and 55 percent shading regimes; and at the age of five months total plant dry weight was optimal under 55 percent shade. At this stage, conditions of 80 percent, 30 percent and 0 shade were detrimental to dry weight accumulation.

Information from growth analyses i.e. relative growth rate (RGR) Leaf Area Ratio (LAR) and Net Assimilation Rate (NAR) *(Figs. 4, 5 and 6)* were, in the main, within the ranges obtained by a number of workers as reviewed by Okali and Owusu (1975). It can be seen that, despite increases in total plant dry weight and leaf area as the plants grew older, LAR decreased with plant age, indicating that the ratio of photosynthetic surface to the total dry weight of the plants decreased with age. This was further reflected in the reduction of RGR and NAR for the same periods. The variation of LAR under the different shading regimes did not show any consistent trend. Mean RGR and NAR, on the other hand, were lowest under full sunlight. Under 80 percent shade RGR and NAR were highest during the first two months of growth, but between the fourth and fifth months NAR was under 30, 55 and 80 percent shade. Optimum RGR at the

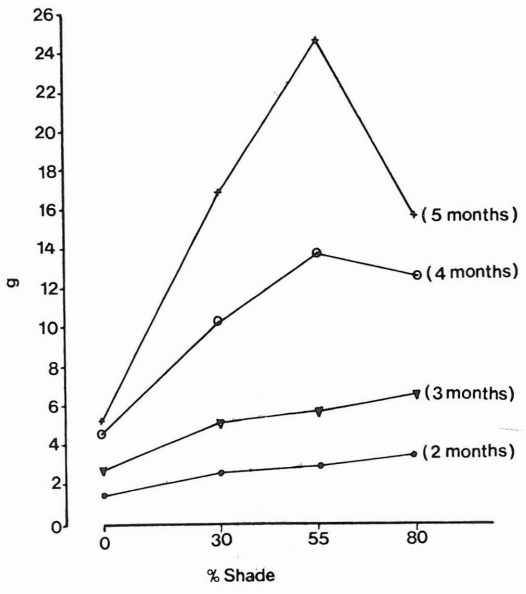

Fig. 3. Dry weight per plant.

$LSD_{p=0.05}$ *shade means* = 1.42

$LSD_{p=0.05}$ *harvest means* = 3.27

$LSD_{p=0.05}$ *shade harvest* = 5.66

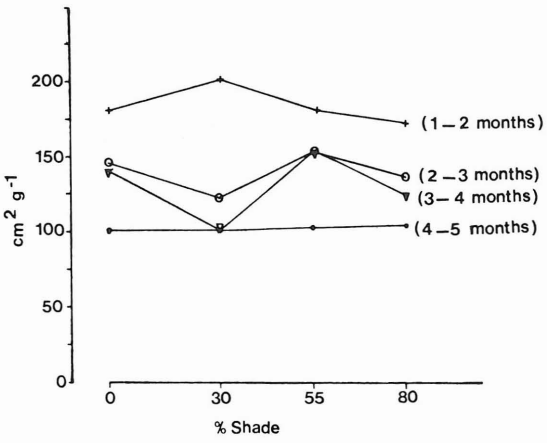

Fig. 4. Leaf area ratio.

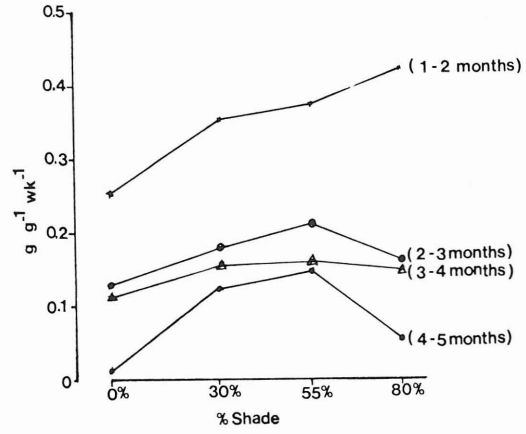

Fig. 5. Relative growth rate.

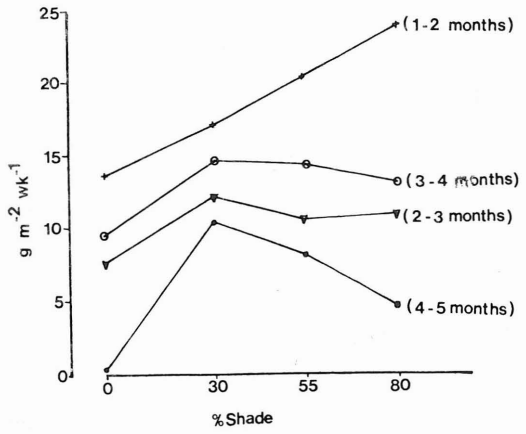

Fig. 6. Net assimilation rate.

ages of 4 to 5 months was under 30 and 55 percent shade.

DISCUSSION

The results of this experiment show that shade requirements for cocoa seedlings change with the age of the plants. Optimum total plant dry weight of cocoa seedlings *(Fig. 3)* of up to three months old is obtained under conditions of 80 percent shade whereas optimum shade for plants of four and five months old is 55 percent. These observations are in agreement with the nursery shade management practice suggested by Sheperd (1976) where 80 percent shade is given during the first few months of growth and gradually decreased as the plants grow older.

The following is an attempt to explain the interaction between age and shade requirement with respect to plant growth.

Data on mean NAR indicate maximum NAR i.e. its light saturation point is in the region of 80 percent shade (20 percent full sunlight) during the first two months of growth; a shading regime lower than 80 percent at this stage of growth, reduces NAR. Light saturation points for photosynthesis have been placed at 20 percent full sunlight for plants developed under full sun and 6 percent for plants under shade by Okali and Owusu (1975) measuring photosynthesis of lead discs. Owusu (1978) in his review on light requirements for cocoa placed light saturation points in the region of 6–30 percent full sunlight, whereas Evans and Murray (1953) indicated an optimum intensity of 45 percent for 12–18 month old plants. The apparent shift in the optimum shading regime for mean NAR from 80 percent to 30 percent shade (20 percent to 70 percent light intensity) in the present experiment *(Fig. 6)* occurs gradually as the plant ages from the second to the fourth month, and becomes very obvious for five-month-old plants. This apparent shift can be explained on the basis of changes to the whole plant canopy. As the plant ages, newer and fairly large leaves shade the lower and older leaves thereby reducing photosynthetic capacity of the latter which consequently reduces the overall NAR. It is only under conditions of higher light intensities i.e. reduced shade such as 55 percent and 30 percent, that the lower leaves on four- and five-month-old plants, could receive sufficient light intensity to compensate for the shading by the upper leaves. However, despite maximum NAR at 30 percent shade for four- and five-month-old plants, optimum total plant dry matter obtained was under 55 percent shade. The axiom that total plant dry matter production is, in the main, a product of its total leaf area and its mean photosynthetic rate, can be used to explain this. Leaf area *(Fig. 2)* for the four and five-month old plants is greatest under 55 percent shade compensating for the slightly lower NAR under this shading regime. It is probable that there exists an internal controlling mechanism to produce, within limits, larger leaf areas under reduced light conditions to compensate for lower NAR as was observed for citrus and mungbeans (Monsi *et al.*, 1962). Under severely shaded conditions of 80 percent, it is likely that available plant resources are not able to produce sufficient leaves to compensate for reduced light.

Under unshaded conditions, i.e. full sunlight, NAR and leaf areas are severely inhibited, reducing RGR and total dry matter production as was observed by Goodall (1955) and Okali and Owusu (1975). Obviously the exposure of ecologically shade adapted plants to full sunlight will subject the plants to stresses such as excessive leaf temperatures (Okali and Owusu, 1975) and increased water loss (Bonaparte, 1966). These stresses can promote a chain of reactions resulting in overall poor nutrient uptake, low photosynthetic rates and overall poor plant growth.

CONCLUSION

It can be concluded that young cocoa seedlings require shading for optimal growth. As pointed out by Alvim (1977) the purpose of shading is not only to reduce light intensity but also to reduce stresses associated with exposure to full sunlight. The present study suggests that an optimum shading regime needs to take into account plant

age, which modifies canopy architecture and net assimilation rate, and the influence of light intensity on the development of leaf surfaces. It is proposed that the practice of initially providing 80 percent shading and gradually decreasing it to 55 percent for plants at four months old onward ensures maximum seedling growth in the nursery.

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