

Use of plastic shades to regulate growth of korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen)

S. Eyob

Horticulture Department, Awassa College of Agriculture, Hawassa University, P.O.Box 5, Awassa, Ethiopia.
E-mail: solomoneyob70@gmail.com

Abstract

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen), a slow growing and persistent under tree shade as an under-story perennial plant, is native to Ethiopia. When it is grown in full sunny condition, all plants die off a few weeks after planting, but the effect of different shading materials on its growth is not known. Half a year old korarima plants were planted under differently coloured plastic shades (red, green, blue and clear) and coffee (*Coffea arabica* L.) tree shade to regulate the growth. The coffee tree shade was used as control. Varying levels of photosynthetic photon flux density (PPFD) and red to far red (R/FR) ratio of light were recorded under different shaded and open conditions. The korarima plant responded differently to the different plastic and coffee tree shades. Average plant height, number of leaves per plant, number of sprouts per plant, chlorophyll content, leaf area, total fresh and dry weights were significantly different when recorded at different stages of growth, highest being recorded under the blue plastic cover. The minimum efficiency was achieved under control.

Key words: Korarima, *Aframomum corrorima*, Mesketo, photon flux density, plastic shade, tree shade, growth regulation.

Introduction

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) belongs to the family Zingiberaceae and native to Ethiopia (Jansen, 1981; Lock, 1997). It has been used as a spice crop in Ethiopia since time of Queen Sheba. The seed, pod, leaf, rhizome and root of korarima are also used as traditional medicine in Ethiopia (Eyob *et al.*, 2008). It is a perennial aromatic shade loving herb; with scaly rhizomes and leafy stems reaching 1-2m height. It grows slowly and persistent under tree canopy as an under-story plant. It is mainly grown in the natural forests dominated by woody species.

Geoffrey and Martin (2000) described that many changes in the environment can occur when the gap is created in the forest. The changes may include alteration in photosynthetically active radiation (PAR), light intensity and quality, temperature, competition for moisture, humidity and nutrient availability. Perhaps the most critical management requirement is needed for a well-adapted shade loving plant species such as korarima, which grow under forest vegetation. Adaptation to shade does not significantly change leaf radiation adsorption efficiency in tree species (Baltzer and Thomas, 2005). However, since plants convert only a small percentage of absorbed radiation into photosynthate facilitating growth, absorption efficiency may not be a relevant measure of adaptation benefits. Plants have evolved very sophisticated sensory networks for monitoring the status of several important features of their surroundings. Shahak *et al.* (2004) reported that the spectral manipulation promotes physiological responses, while light scattering improves light penetration into the plant canopy.

Korarima is traditionally grown in home gardens under tree shades, and in the natural forests in association with wild coffee

(*Coffea arabica* L.). Review of indigenous production practices in Ethiopia showed a decreasing trend in production areas and yield in two decades as a result of shortage of permanent shade trees in the household farms and destruction of natural forests. As reported previously by Kendrick and Kronenberg (1994) the economic success of crop production requires proper management of the solar radiation resource as light quality has a significant effect on plant growth, development and productivity. With respect to korarima, it is well known fact that its cultivation is unsuccessful where the shade trees are not available. Hence, the need for permanent tree shades hinders large scale production of crop. Uses of covers that block parts of the incoming radiation have been used in areas with high solar radiation and excess temperatures. Therefore, the objectives of this study were to determine the comparative advantages and optimal shade management strategies using locally produced plastic films over tree shades and open conditions for growth of korarima.

Materials and methods

Plant material and experimental design: Approximately half a year old planting materials from cultivar Mesketo were planted (one plant per pot) in plastic pots (Ø 40cm) filled with forest soil and compost mixture, and grown in the protected garden of Horticulture Department, Hawassa University, Ethiopia. The plants were managed properly as per agronomic practices. Four plastic pots were replicated three times for each treatment consisting of 12 pots per treatment in completely randomized design. Locally produced photo selective red, green, blue, and clear plastic films partially transparent for sun light were used as experimental treatments. Coffee tree shades were used as control treatment. The plastic films used for this purpose are commonly used as shades in the local open markets and road sides in Ethiopia. The plastic films were mounted on sticks ca

2m above the ground. On all sides, 1 m above the ground, the plastic shades were open to maintain free air circulation at the same level as the shades from the coffee trees. The coffee trees grew ca 35m from plastic shades and were used to simulate natural growing condition of korarima. Twelve pots were placed under open conditions for purpose of comparison.

The photosynthetic photon flux density ($\mu\text{molm}^{-2}\text{s}^{-1}$) and red to far red ratio of light were measured under different plastic shades, coffee trees and open condition by using a SKP 215 PAR Quantum Sensor before the plants were planted (Table 1).

Measurements: Sixty days after planting (DAP), number of fully opened leaves per plant and number of newly emerging young shoots at the base of mother plants and chlorophyll content were recorded on a monthly basis from June 2005 to May 2006. A field portable, hand held chlorophyll content meter (Model CL-01, Hansatech Instruments Ltd, England) was used at day time from 2: 00 to 3:00 p.m. to estimate average total chlorophyll content in leaves of korarima. Leaf area was measured using portable leaf area meter, Model LI-3000A after removing all leaves from plants grown for destructive measurements and average leaf area was estimated for a single plant at 300 DAP. In the end of the experiment fresh and dry weights were recorded. Total fresh weight of sampled plants was measured at 360 DAP and the dry weight was recorded after oven drying at 100°C for 2 days. Soil particles and any debris were removed from roots before taking measurements.

Data analysis: The data were analysed as a completely randomised design with repeated measurements three times. Fisher least significant difference (LSD) test was used to compare means at $P=0.05$. On randomly selected plants regression analysis was carried out on the number of sprouts per plant and leaf number per plant as independent and dependant variables, respectively to see any relationship and trends in growth of korarima at 240 DAP. The software used for this statistical analysis was MINITAB 13th edition.

Results

The varying coloured plastic sheets significantly affected PPFD and R/FR level under plant canopy inside the shades. As a consequence of extreme increase of PPFD ($1410 \mu\text{molm}^{-2}\text{s}^{-1}$) and R/FR (1.12) under open condition (Table 1), plants showed very slow rate of increase in shoot height for four weeks (data not shown) and died off afterwards while those under shade showed a continuous growth. Under shaded conditions, the plants showed significant differences between the treatments with regard to growth performances at $P=0.05$. The variation in

Table 1. Photosynthetic photon flux density (PPFD) and red to far red (R/FR) ratio of light under different shading and open conditions

| Shading materials | PPFD ($\mu\text{molm}^{-2}\text{s}^{-1}$) | R/FR |
|-----------------------------|--|------|
| Red plastic | 680 | 0.98 |
| Green plastic | 462 | 0.68 |
| Blue plastic | 243 | 0.66 |
| Clear plastic | 790 | 1.01 |
| Coffee tree shade (control) | 102 | 0.53 |
| Open condition | 1410 | 1.12 |

Table 2. Effect of plastic shading on plant height (cm) of korarima at different stages of growth

| Treatment | Days after planting (DAP) | | | | | |
|---------------|---------------------------|------|------|-------|-------|-------|
| | 60 | 90 | 120 | 150 | 180 | 210 |
| Red plastic | 29.3 | 33.7 | 48.0 | 72.7 | 75.3 | 77.0 |
| Green plastic | 32.3 | 49.7 | 61.0 | 86.00 | 88.3 | 81.7 |
| Blue plastic | 34.7 | 71.3 | 83.3 | 104.8 | 106.0 | 109.0 |
| Clear plastic | 22.7 | 31.3 | 43.0 | 61.7 | 65.7 | 74.7 |
| Control | 23.3 | 27.0 | 37.0 | 56.4 | 58.3 | 68.3 |
| LSD | 6.3 | 19.9 | 21.1 | 16.2 | 15.3 | 15.4 |

Table 3. Effect of plastic shading on leaf number per plant

| Treatment | Days after planting (DAP) | | | | | |
|---------------|---------------------------|------|-------|------|------|------|
| | 60 | 90 | 120 | 150 | 180 | 210 |
| Red plastic | 8.0 | 8.7 | 9.7 | 11.0 | 11.3 | 12.3 |
| Green plastic | 9.3 | 11.3 | 14.00 | 16.7 | 17.3 | 18.3 |
| Blue plastic | 11.3 | 13.7 | 15.7 | 17.3 | 19.0 | 20.0 |
| Clear plastic | 5.0 | 8.7 | 10.7 | 11.3 | 11.7 | 12.3 |
| Control | 3.0 | 4.0 | 6.7 | 8.7 | 10.3 | 11.3 |
| LSD | 5 | 5.8 | 4 | 3.5 | 3.4 | 3.4 |

Table 4. Effect of different shade treatments on the leaf area, fresh weight and dry weight per plant

| Treatment | Leaf area (m^2) | Fresh wt (g) | Dry wt |
|---------------|----------------------------|--------------|--------|
| | 300 DAP | 360 DAP | (g) |
| Red plastic | 3.31 | 2982.5 | 231.4 |
| Green plastic | 3.80 | 3075.1 | 262.0 |
| Blue plastic | 4.22 | 3766.4 | 394.9 |
| Clear plastic | 2.13 | 2029.2 | 193.8 |
| Control | 1.62 | 1633.9 | 112.7 |
| LSD | 0.23 | 351.1 | 51.2 |

plant height between treatments was significant (Table 2). For all the treatments, there was a gradual increase in plant height from 60 DAP to 210 DAP. However, shoots under the control treatment were weak and slow in the growth. Remarkably strong and erect plants were observed under blue plastic sheet compared to other treatments. Significantly higher plant height (109.0cm) was recorded at 210 DAP in blue plastic sheet compared to the control (68.3cm) when recorded on the same date.

In case of leaf number also, the variation between treatments was significant (Table 3). There was a gradual increase in leaf number in different stages of growth. The increase under the control was low. Significantly increased leaf number was recorded in blue plastic (20.0) as compared to the control (11.3), clear plastic (12.3) and red plastic (12.3) at 210 DAP. Changes in leaf number for the clear plastic and the control were low during growth period.

The varying coloured plastic sheets induced a significant effect on the number of sprouts per plant in almost all the treatments used (Fig. 1). The number of sprouts were most enhanced with about 50% of increase in blue sheet when compared with the control and clear sheet starting from 150 DAP to 210 DAP. The other treatments showed about 20-30% increase over the control and clear plastic.

The variation in leaf area at 300 DAP due to shading effect was significant. Plants grown under blue plastic shade had the highest leaf areas (4.22m^2) compared to the control (1.62m^2) and other treatments (Table 4).

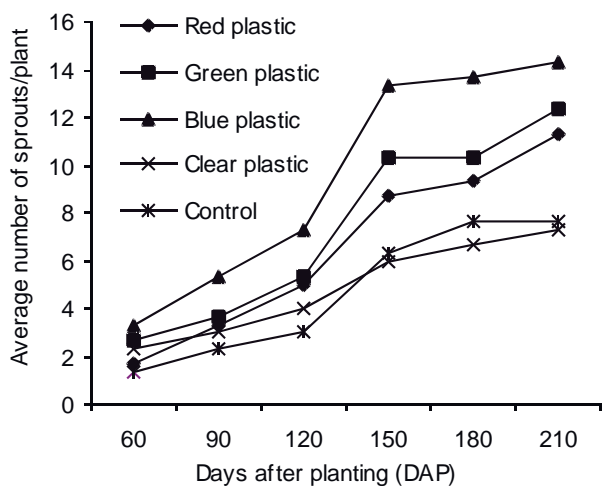


Fig. 1. Effects of artificial shading materials on average number of sprouts per plant at different stages of growth.

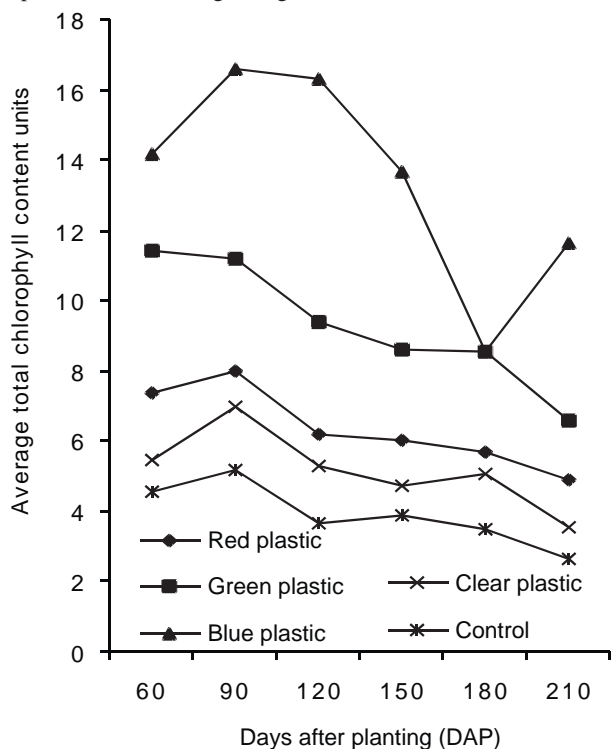


Fig. 2. Effect of artificial shading materials on average chlorophyll content of korarima at different stages of growth.

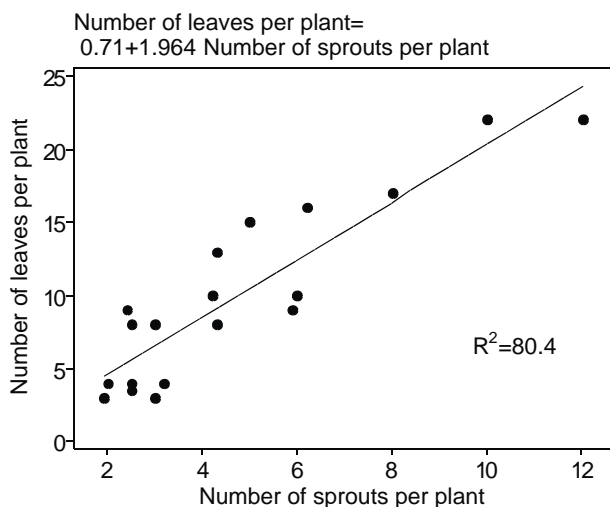


Fig. 3. Linear relationship between sprouts number per plant and leaves number per plant at 240 DAP.

The shade treatments increased fresh and dry weight. The highest fresh (3766.4g) and dry weight (394.9g) were recorded under blue plastic shade (Table 4). Increase in leaf area accounted wholly for the increase in plant fresh and dry weight.

The chlorophyll content in leaf was affected significantly by shade treatments, the highest being recorded in blue plastic shade when recorded at 90 DAP and the lowest was in the control (Fig. 2). In all treatments the chlorophyll content gradually decreased after 90 DAP. However, under blue plastic shade they seemed to increase again after 180 DAP.

The varying level of PPFD and R/FR induced by different shading materials showed considerable difference on korarima growth. The PPFD ($102.2 \mu\text{mol m}^{-2}\text{s}^{-1}$) and R/FR (0.53) under the control treatments resulted in poor growth performances of korarima. On average 82.8% decrease and 58% increase in PPFD by blue plastic shade over open condition and control, respectively, regulated growth of korarima. Most of the growth characteristics were highest at interaction level of PPFD at $243 \mu\text{molm}^{-2}\text{s}^{-1}$ and R/FR at 0.66 under blue plastic.

The simple linear regression analysis showed a significant relationship between sprouts per plant as independent variable and leaf number as a response variable when tested at $P=0.05$. For a unit increase in sprout number per plant, there was linear increase in leaf number by 1.964 as indicated in Fig. 3. It is clear that 80.4% variability ($R^2=0.804$) in leaf number per plant could be explained by sprout number per plant.

Discussion

The potential importance and results obtained from growth performance of korarima are presented in this study. Shading materials significantly influenced the rate of vegetative growth of korarima. In the blue plastic shade, plant vegetative growth was significantly promoted. The growth performance of the plant was reduced in all stages of growth under tree shades indicating that tree canopy intercepted most part of incoming solar radiation. This explains the existing fact that korarima is indigenous slowly growing species in the forests of Ethiopia as they appear more or less isolated or in clumps under trees. Total death of plants under open condition might be due to heat from a high portion of near infra-red radiation (NIR, 700 to 1100nm).

It was observed that the plant height under plastic shade showed greater increase in length compared to those of under control. The remarkable increase in plant height, leaf number and number of sprout under blue plastic shade during growth period over other treatments indicate differences in response of the rate of growth under the various light regimes. In our experiment, etiolated and very weak plants with dull green leaves were observed under the control as compared to plastic shades explaining the need of enough light sources during photosynthesis for the manufacture of food. In the shortage of light, sufficient energy is not available for plants as observed in control.

Leaf area increased faster under blue plastic due to a higher leaf appearance rate, which made possible the growth of young sprouts at the base of mother plant, as photosynthetically active leaves were available. After 90 DAP chlorophyll content in leaf was declined gradually under all shade treatments implying the

assimilation of photosynthetic products for growth by young growing sprouts. The increased total fresh and dry weights per plant at maturity were associated with enhanced effect of leaf area production under blue plastic.

Compared to other plastic colours, blue plastic decreased PPFD and R/FR to optimum level and resulted in better growth performance of korarima as a result of the partial control of climate inside the plastics. The significance of the climatic control systems inside the greenhouses have been suggested by Arellano *et al.* (2006). This experimental finding shows that artificial coloured covering materials are effective in regulating vegetative growth. This is in conformity with finding of Donald *et al.* (2005), Murakami *et al.* (1997), and Rajapaske and Kelly (1992). Generally with moderate reduction of PAR, there were increase in korarima growth performance. The overall effect of heavy shading resulted in tiny and a poorly grown plant under the control, which is in agreement with work of Bartlett and Remphrey (1998).

The results reported in this work, in brief, suggest that in the absence of enough forest gaps for sufficient light quality to infiltrate and initiate better growth of korarima, physiological and morphological response would be affected negatively. The difference in growth response achieved due to shade treatments suggests various possibilities of field management strategies using locally available plastic sheets which could vary depending on light source to optimise production. Moreover, korarima response to various level of PAR suggesting a high degree of flexibility in terms of growth and resource utilization even though the korarima plant exist in the forest under natural conditions. Further we suggest development of new korarima varieties through conventional breeding and molecular techniques for maximum and efficient utilization of total light sources under open conditions to promote production at large scale in the future, which also avoids cost of shading materials.

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