

Effect of Light Stress on Germination and Growth Parameters of *Corchorus olitorius*, *Celosia argentea*, *Amaranthus cruentus*, *Abelmoschus esculentus* and *Delonix regia*

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Abstract

Seeds of *Abelmoschus esculentus*, *Amaranthus cruentus*, *Celosia argentea*, *Corchorus olitorius* and *Delonix regia* were germinated under light and dark conditions. The germination parameters revealed that germination was higher in seeds of *A. cruentus* and *C. olitorius* under light while the seeds of *D. regia* germinated more in the dark. However, no major difference was observed in the germination of *C. argentea* and *A. esculentus* in light and darkness. The above findings point out that germination is species dependent. It also indicated that *Amaranthus cruentus* and *C. olitorius* adapt better to light while *D. regia* adapt better to dark condition. The shade plants of *A. esculentus* and *D. regia* were found to be taller than those under direct sunlight. However, seedlings of *A. cruentus*, *C. olitorius* and *C. argentea* were found to be taller those under direct sunlight than in the shade regimes. This could suggest that these plants have higher tolerance of heat with respect to *A. esculentus* and *D. regia*. Shade plants of *A. esculentus*, *C. argentea*, *C. olitorius* and *D. regia* exhibited lower leaf area which is an adaptation to maximize light interception. Higher leaf area was observed in the shade plant of *A. cruentus* may be an adaptation to maximize the little light available to the plant under shade. These findings revealed plants adaptation to cope with stress in the environment.

Keywords: adaptation, environment, regime, shade, tolerance

Introduction

Light plays a critical role in plant growth and development as its quality, quantity and direction are perceived by photo-sensory which collectively regulate plant development, presumably to maintain photosynthetic efficiency (Hangarter, 1997). The different photochemical systems found in plants are able to sense changes in duration, direction and spectral quality of light. The activating process in plants results in qualitative modification of growth and developmental pattern in response to changes in the environment. For example phytochrome action, photoperiodism, breaking of dormancy, flowering and many more are affected by light.

Seed germination is often the most sensitive stage in the life cycle of a plant. Seed germination can be defined as the growth of the embryo of the mature seed, and this depends on environmental conditions such as water and oxygen availability as well as temperature (Bonnewell *et al.*, 1983; Meredith, 1985).

According to Cantliffe (1998), seed germination is a critical step to achieve economic success in a transplant operation. Total germination of a seed lot dictates total plant sales by the producer, while uniformity of germination dictates the quality of the most important step to help

ensure economic returns. Germination of crop seeds follows a specific sequence of events. They include: imbibition of water, enzyme activation, initiation of embryo growth, rupture of the seed coat, and emergence of the seedling (Kigel and Galili, 1995). This marks the end of germination and the beginning of seedling growth. Germination of seeds may be affected by several environmental factors. It is complex process that is controlled by several biological (species, seed viability, seed dormancy, seed size) and environmental (moisture availability, temperature, relative humidity, light intensity and duration) factors. Since plant species vary in their response to these factors, it is important to determine the optimum conditions and seed treatments for germination and seedling establishment under the prevailing climatic conditions (Sakpere, 2011).

C. olitorius is an exotic annual dicotyledonous herb. It is widely distributed in tropical and sub-tropical region. Consisting of galacturonic acid, galactose, mannose, glucose and arabinose. *C. argentea* belongs to the family Amaranthaceae. It is a wide spread weed throughout tropical Africa, and a traditional vegetable in West and Central Africa. It is one of the leading leaf vegetables in south-western Nigeria. *C. argentea* 'Argentea' or 'Lagos spinach' is one of the main boiled greens. *D. regia* is a tree species from family Fabaceae which noted for its fern-like leaves and flam-

boyant display of flowers. The tree's vivid red/vermillion/orange/yellow flowers and bright green foliage make it an exceptionally striking sight. *Amaranthus cruentus* belongs to the Amaranthaceae family. It was domesticated as a pseudo-cereal. Vegetable amaranthus are recommended as a good food with medicinal properties for young children, lactating mothers and for patients with constipation, fever, haemorrhage, anaemia or kidney complaints (Kauffman and Gilbert, 1981). *A. esculentus* belongs to the family Malvaceae. Okra mucilage is suitable for medicinal and industrial applications. It has been used as emollients, and to treat dysuria (difficulty to urinate). The composition of okra fruits per 100 g edible portion (81% of the product as purchased, ends trimmed) is: protein 2.1 g (1.1-3.0), fat 0.2 g, carbohydrate 8.2 g, fibre 1.7 g.

Fluctuation in light intensity can lead to stress in plants. Light as an energy source for plant life is known to affect plants dually. It affects photosynthetic rate and assimilate accumulation, thereby playing a substrate role; it also controls growth and development, in that way, it plays a regulatory role (Sysoeva et al., 2010). Many authors have confirmed the importance of high light intensity on seedling, growth and survival. Mayer and Mayber (1982) and Osunkoya et al. (1994) found that many trees reduced their growth (e.g. root size and weight) with reduced light intensity. Moreover, Alvarez-Buylla and Martinez-Ramous (1992) indicated that reduced light was one of the factors that led to the mortality of young plants. Teremura (1983) reported that though solar radiation could be beneficial to plant growth, but the extreme could be harmful as it may lead to water shortage through evaporation and cause dehydration. Growth of plants in the natural environment is subject to varying light conditions depending on whether they are in the open field situation or under shade. Sunlight passing through a plant canopy is attenuated or reduced in intensity and quality due to selective absorption in certain wavelength by plant pigments (Aileme, 1995). Bean plants in shaded condition respond to low light by devoting more of their available carbon to shoot growth resulting in part to taller stem (Hoddinott and Hall, 1981). McLaren and Smith (1978) found that the shade plant *Rumex obtusifolius* has reduced leaf area and reduced dry weight. There is an effect called 'Emerson enhancement effect' which serves to increase the overall rate of photosynthesis under shade conditions (Hoddinott and Hall, 1981). Different plants respond in different ways to canopy light (Chatterson and Silvinus, 1981).

There is normally a decline in the rate of photosynthesis and translocation from shade condition to sunlight (Aileme, 1995). This is because the transfer of photosynthetate to the sink in the sun plants, which is at a greater rate; that is there is a low photosynthetic efficiency and high assimilation in the sun and high photosynthetic efficiency and low assimilation in shade conditions. Expansion and translocation differ in both conditions depending on the nature and duration of light treatments. Sink

strength can depend on the activity and size of the sink in terms of growth rate and this increase in sink size is caused by shade light conditions (Hoddinott and Hall, 1981).

Seeds usually germinate at low light intensities, as reported by some authors, e.g., Hartmann and Kester (1975) and Sacande and Some (1992). A study on the germination of *Phalaris arundinacea*, reported that there was a high germination percentage under dark conditions (38%) and it was stated that "germination is not accelerated by light as in many other grass seeds, and may be even light inhibited in some cases" (Cisneros and Zedler, 2001). This is in agreement with the theory that phytochrome is the main sensor for light regulated seed germination. This principle allows the embryo to germinate in the absence of light (Raven and Santana, 1999). Lopez and Sanchez (1989) and Dan and Brix (2007) reported that seeds of *Sesbania sesban* can germinate without light. Plants exposed to strong light can have their photosynthetic apparatus damaged or injured (Aileme, 1995). Damage to photosynthetic apparatus is caused by wavelengths in the ultraviolet region (Caldwell, 1980), by light in the invisible part of the spectrum and by interaction between the visible and the ultraviolet part (Warner and Caldwell, 1983). Working with soybean, they discovered that high visible radiation can reduce the inhibition of photosynthesis of higher plants by the ultraviolet- β radiation.

Crop yield is photosynthetically limited. Light fosters active transport of solutes across membranes, it stimulates uptake of sugar by sink (sugar utilising area or tissue). If the source (sugar producing areas) supply, phloem loading, short term storage and under sink uptake were influenced by irradiance, there might be a reduced sink growth under low light without any change in sugar concentration in source and sink (Grifford and Evans, 1981). The objectives of this study is therefore to investigate the effect of light and nutrient on some germination and growth parameters of *C. olitorius*, *C. argentea*, *A. cruentus*, *A. esculentus* and *D. regia* with a view to determine their threshold of adaptability to various stress conditions.

Materials and methods

Seed collection

Seeds of *A. esculentus*, *A. cruentus* were obtained from National Horticulture Research Institute (NIHORT), Ibadan while seeds of *C. argentea*, *C. olitorius* from Institute of Agricultural Research and Training (IART), Apata, Ibadan. The seeds of *Delonix regia* were collected from local plants in Obafemi Awolowo University, Ile-Ife.

Germination Experiment

The effect of light on germination was investigated by placing the Petri dishes under three treatments or regimes. In one treatment, the Petri dishes were placed under a light chamber emitting average light intensity of 2750 lux from white fluorescent tubes for 2 hours daily. In the second

treatment, the Petri dishes were kept in a cupboard creating the dark environment while the last treatment was the control in which the Petri dishes were placed in the open space beside the Department of Botany, Obafemi Awolowo University, Ile-Ife under ambient conditions and under natural light emitting average light intensity of 48400 lux daily.

Germination testing was done in 9-cm sterile Petri dishes lined with Whatman filter papers each containing twenty seeds for each plant. Five replicates were prepared for each treatment with respect to each plant and these were moistened using distilled water via a water bottle when needed. The Petri dishes were examined daily and seed was considered germinated when the radicle was visible. The germinated seeds were counted daily during the fourteen day-experimental period.

Scarification of seeds

During the course of the experiment, seeds of *D. regia* did not germinate. Seeds which did not germinate were later scarified to break dormancy which may be as a result of the seed coat properties. The seeds were scarified by leaching in distilled water using a Griffin Flask to remove some inhibitors after which their seed coats were scarified slightly with the aid of a sharp blade. The germination experiment was then repeated.

Germination parameters

Total germination was recorded and expressed as percentage (Ranal and Santana, 2006) using the formula:

$$\text{Germination percentage (\%G)} = (\text{tng}/\text{tnp}) \times 100$$

Where tng = total number of seeds germinated, and tnp = total number of seeds planted.

Mean germination time (MGT), proposed by Haberlandt in 1875 (Labouriau, 1983) was calculated. It is a measurement of the average length of time required for maximum germination of a seed lot, and is expressed in terms of the same units of time used in making germination counts (hours or days). It is denoted as:

$$\text{MGT} = (\text{G}_1\text{T}_1 + \text{G}_2\text{T}_2 + \dots + \text{G}_n\text{T}_n) / (\text{G}_1 + \text{G}_2 + \dots + \text{G}_n)$$

Where G: germination count on any counting period; T: time.

The mean germination time was used to evaluate seedling emergence.

In order to calculate speed of germination, seedling emergence was counted on a daily basis. From the data recorded, speed of germination, mean daily germination (MDG) which is the mean number of seeds germinating per day, and germination value (GV) which is an index that expresses speed and totality of germination, and their interaction (Czabator, 1962) were then computed as shown below:

Speed of germination (SG) = (number of seeds germination/days of first count) + ... + (number of seeds/germination percentage/number of days

Peak value (PV) = Cumulative percent germination on each day/number of days after germination elapsed
(GV) = PV x MDG.

Growth experiment

Sand was collected at the base of Hill 1 in Obafemi Awolowo University Ile-Ife, Osun State. The sand was transferred into nine plastic pots containing bored holes at the bottom to allow for drainage during the course of the experiment. The pots each of which was 21cm in diameter were filled near brim with the sand. After germination, seedlings of *A. esculentus*, were transplanted to the pots. The seedlings were watered daily with 100ml of distilled water in the morning and 100 ml of distilled water in the evening until they were fully established. The established seedlings were raised under direct natural sunlight before the experiment commenced. This process was also replicated for *A. cruentus*, *C. argentea*, *Corchorus* and *D. regia*.

On the fifteenth day after planting which is beginning of week 0, the pots were divided into three groups each containing five pots, each pot containing a seedling of each test plant. The three groups (regimes) are described below:

- The first group (control) was made to receive direct sunlight emitting an average of 48400 lux of light, by placing them in the open space beside the Department of Botany, Obafemi Awolowo University, Ile-Ife.
- The second group (shade 1) was placed under the shade provided by the staircase beside the Department of Botany, Obafemi Awolowo University Ile-Ife, adjacent to the main road, receiving average light intensity of 10000 lux.
- The third group (shade 2) received average light intensity of 16300 lux and was placed under the shade provided by the Tecoma stans tree beside the Department of Botany, Obafemi Awolowo University, Ile-Ife.

The intensities of light were measured with a digital lux meter. The seedlings in all the three groups received 100 ml of distilled water daily for five weeks.

Light measurement

A digital lux meter was used to measure solar radiation in full sunlight and under the shades, as well as light intensity in the light chamber.

Measurement of morphological parameters

A metric rule was used to measure the following morphological parameters: leaf length and width, shoot height from the surface of the soil to the terminal end.

The leaf area was calculated according to Hoyt and Brandfield (1962) as shown below:

$$\text{LA} = \text{LL} \times \text{LB} \times 0.75$$

Where: LA is the leaf area

LL is the leaf length

0.75 is the correction factor for the leaf shape

The numbers of leaflets of *D. regia* were monitored as well.

Statistical Analysis

Multivariate analysis of variance was carried out to investigate the effect of light stress on the germination parameters with respect to the test plants. Also, a two-way analysis of variance (ANOVA) was carried out to investigate the effect of light stress on the growth parameters.

Results and Discussion

In this present study, all the conditions that are necessary for the normal growth and development of the tomato seedlings were maintained except that certain seedlings were exposed to light stress. Other environmental conditions were the same for all the seedlings throughout the experimental period. It can thus be inferred that any differences noticed during the course of this experiment would be as a result of the light stress.

The speed of germination is a direct measure of seed vigor (Khan *et al.*, 2003b). Vigorous seed lots have more germination speed compared to non-vigorous seeds (Khan *et al.*, 2003a). Thus, the observed increase in germination speed in *A. cruentus*, *C. olitorius* and *C. argentea*, as well as in the control regimes of *A. esculentus* and *D. regia* (Fig. 1). This indicates that light has positive effect on speeding up the germination process as it brought about increase in germination. These results are supported by the earlier findings of Sivritepe and Dourado (1995) in pea seeds. The mean germination time on the other hand, showed no significant variation between the light and dark regimes except in *Amaranthus cruentus* (Fig. 6).

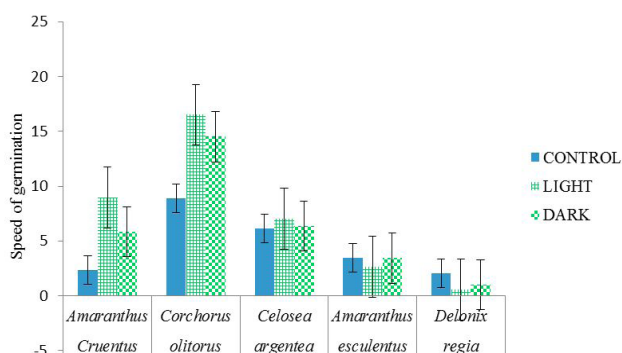


Fig. 1. Speed of Germination of the varieties under different treatments

The other germination parameters of *C. olitorius* and *A. cruentus* indicated high values in the light regime compared to the dark regime indicating that they would germinate efficiently in light than in dark environment. This agrees with the findings of Ehiagbonare and Onyibe (2008) that quality seedlings can be grown in light condi-

tion. In contrast, high values of the parameters were observed in the control and dark regime of *D. regia*.

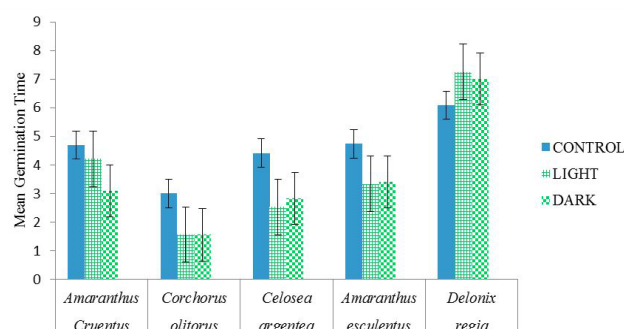


Fig. 6. Mean Germination Time of the varieties under different treatments

This suggests that seeds of *D. regia* will germinate better in an environment with longer period of darkness than light (Fig. 3 and Fig. 5).

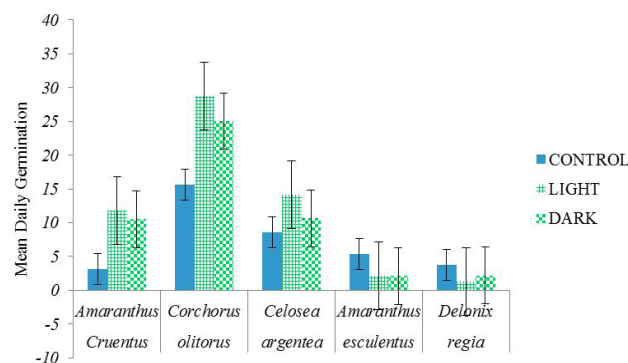


Fig. 3. Mean Daily Germination of the varieties under different treatments

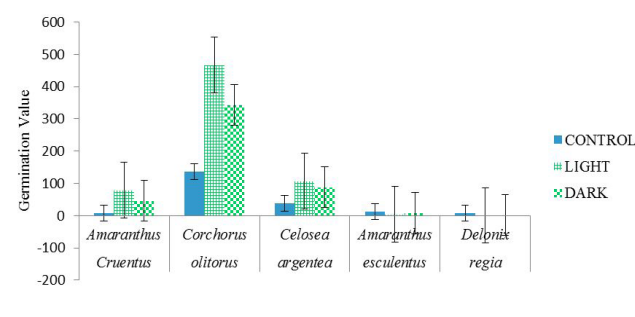


Fig. 5. Germination Value of the varieties under different treatments

The decrease in germination of *D. regia* seeds in the light regime may due to the fact that light may induce the production ABA (Absciscic acid) at certain temperatures thereby slowing down germination (Karsen, 1976). The germination parameters of *Celosea argentea*, *Abelmoschus esculentus* showed slight variations between the dark and light regimes. However, there was no significant difference between the germination percentage in the dark and light

regimes of *C. argentea* (Fig. 2). This could be an indication that it would germinate better in both environments (Fig. 4). The higher peak value and germination value in the dark regime of *A. esculentus* suggests germination might be enhanced by slight increase in dark periods. This is in accordance with the results of Serrano-Bernado and Rosua (2007) who found that some species such as *Gernista versicolor* germinated easier under darkness at low temperature while *Thymus serpylloides* presented maximum germination under constant light to a higher temperature. Thus, it can be inferred that germination is species dependent. Germination is affected by the length, quality and photon irradiance of the light reaching the seed (Casal and Sanchez, 1997). For many species from different habitats, responses to light are mediated by phytochrome perception of the light environment (Roundy and Sumrall, 1992; Casal and Sanchez, 1998).

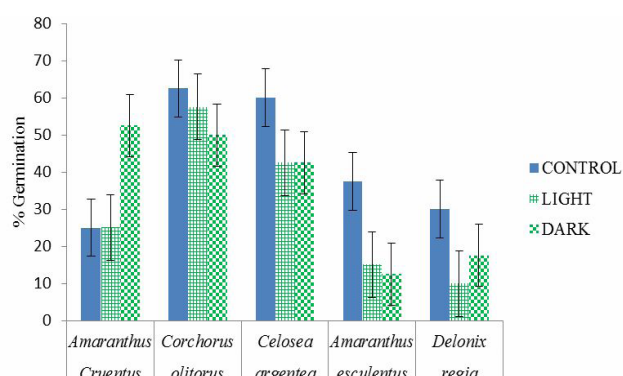


Fig. 2. Percentage germination of the varieties under different treatments

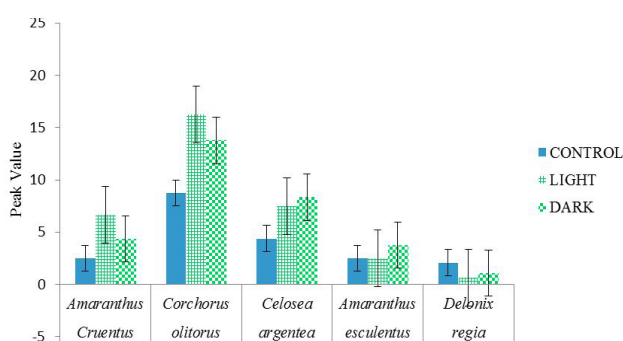


Fig. 4. Peak Value of the varieties under different treatments

The observed higher plant height in shade 2 of *Abelmoschus esculentus* and *D. regia* agreed with the result of Warrington and Morgan (1988) and Ninemetes (1999) who found typical morphological response under conditions of low photo flux density (PTD) as an increase in stem elongation and a reduction in leaf dry mass per area (Figs. 10 and 11). High light intensities may be excessive for optimum growth regulation and photosynthetic activity. The survival of the plants under the shade depends on the efficiency with which they capture and utilize light.

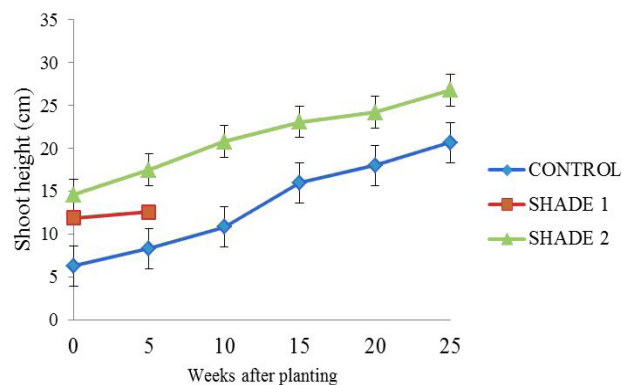


Fig. 10. Shoot height of *Abelmoschus esculentus* under different treatments

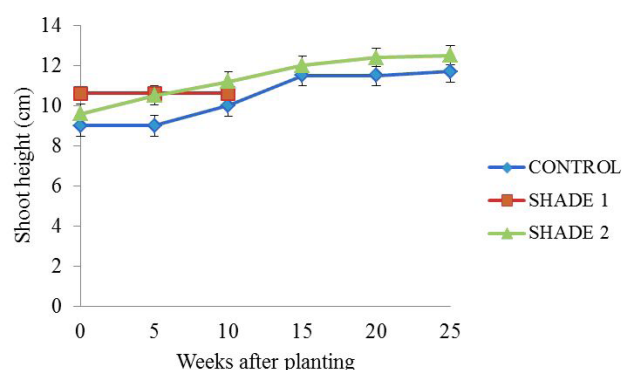


Fig. 11. Shoot height of *Delonix regia* under different treatments

According to Weiner and Thomas (1990), stem extension plays an important role in determining exposure of leaves to light, shading of competitors, and elevation of reproductive structures. Variation in temperature greatly affects plant growth and flowering. These results are in agreement with the results of Mortensen and Larsen (1989), who observed a decreased in shoot length at high light intensity. Shaded plants showed increased stem elongation which is considered to be due to photosynthetic limitation under low light condition. Kephart and Taylor (1992) found that increased stem elongation was associated with moderate reductions in irradiance, which is influenced by photosynthate availability and photosynthate partitioning into stem growth. Kephart and Taylor (1992) however pointed out that stem elongation may not occur when irradiance is reduced to a level where plant developmental processes become photosynthate limited. This was observed in all the plants under the shade1 regime which showed little or no growth at all before dying. Higher plant height was observed in the control regimes of *A. cruentus*, *C. olitorius* and *C. argentea*. This implies that these plants may have higher tolerance of heat compared to the *A. esculentus* and *D. regia*. This is in accordance with the work of Rivero and Garcia (2001) in which the highest shoot height of watermelon, which tolerates

greater heat than tomato, occurred in the highest temperature regime (Figs. 7, 8 and 9).

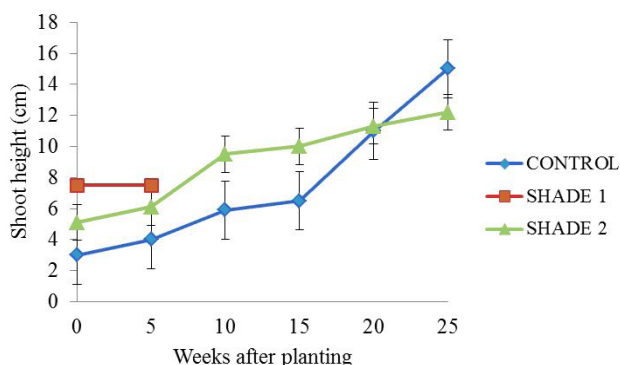


Fig. 7. Shoot height of the *Amaranthus cruentus* under different treatments

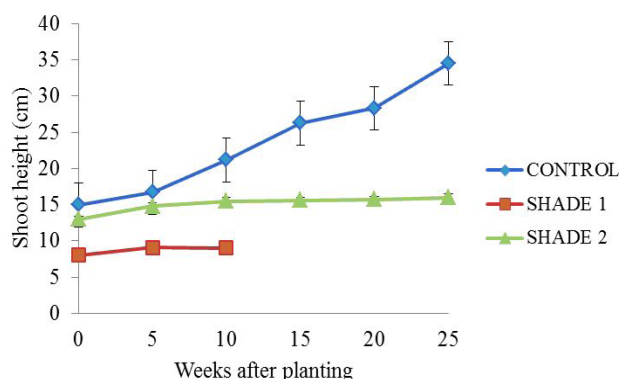


Fig. 8. Shoot height of *Corchorus olitorus* under different treatments

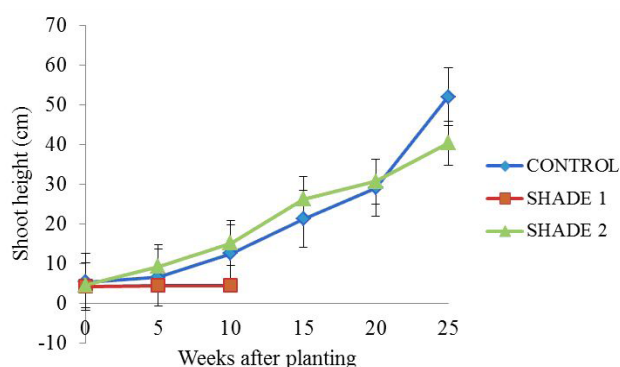


Fig. 9. Shoot height of *Celosia argentea* under different treatments

The lower leaf area in plants under the shade compared to plants in the control with the exception of *A. cruentus*, is supported by the result of Devkota and Hogson (2000) who found that morphological adaptation of plants to low light intensities results in longer and narrower leaves with higher specific leaf area to maximize light interception. Leaves of plants grown in full sunlight had increased leaf

length, leaf width and consequently increased leaf area. This can be attributed to the fact that leaves grown in full sunlight had higher stomatal conductance (g_s) (Boardman, 1977) than shade leaves (Fig. 13).

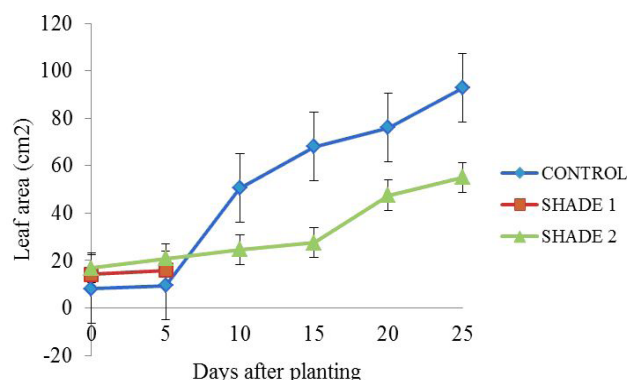


Fig. 13. Leaf area of *Celosia argentea* grown under different light treatments

However, the higher leaf area observed in shade2 of *Amaranthus cruentus* may be an adaptation to maximize the little light available to the plant under shade so as to increase photosynthate production since it is essential for the process of food production so as to compensate for the increasing cell elongation, which is characteristics of the plants under light stress. It increases the photosynthetic surface thereby increasing the light trapping efficiency. This is consistent with the work of Levitt (1980) who showed that light inhibits excessive cell enlargement. The leaf length and leaf width were also shown to be greater in plants under light stress (Patterson, 1979) and this in turn influences the leaf area of the plants (Fig. 12).

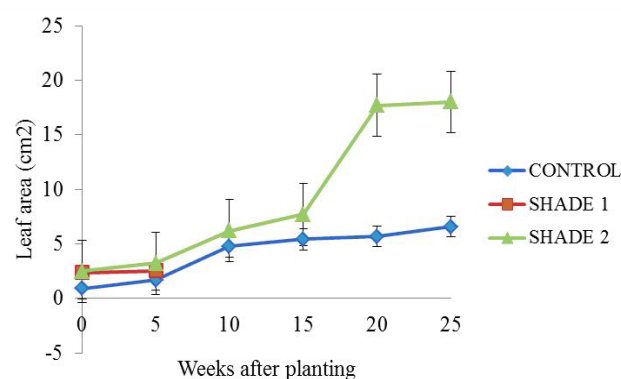


Fig. 12. Leaf area of *Amaranthus cruentus* grown under different light treatments

The highest number of leaflets of *D. regia* was observed in the control regime. This is in agreement with the work of Singh (1978) who reported that in spring barely reduced light intensity decreased leaf number but increased leaf area. However, Katring (1979) found leaf number in peanut, to be equal at both low and high light intensity

could be a mechanism evolved by the plant to increase total surface area for photosynthesis (Fig. 14).

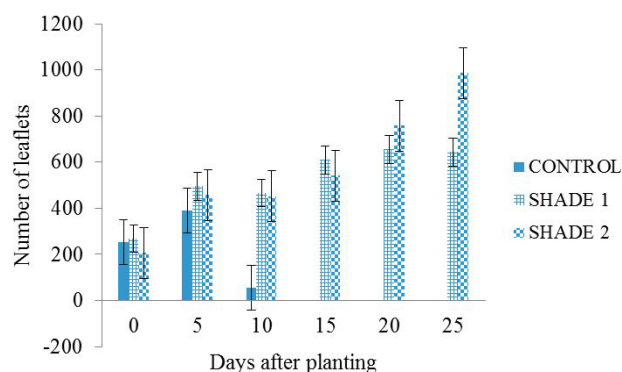


Fig. 14. Number of leaflets of *Delonix regia* grown under different light treatments

Conclusions

In conclusion, the study showed that light stress had effects on the germination, growth and development of plants. It reveals that seeds of *A. cruentus* and *C. olitorius*, germinated better under light. There was variation in the germination of *C. argentea* and *A. esculentus* in light and dark treatments. However, seeds of *D. regia* germinated better in the dark. Thus it can be said *A. cruentus* and *C. olitorius* adapt better to light while *D. regia* adapt better to dark condition. However, further research needs to be carried out to determine the adaptability of *A. esculentus* and *C. argentea* to light and dark conditions due to the variations observed in the germination parameters. Most variables analysed in this study showed that growth of *C. olitorius*, *A. cruentus*, *D. regia*, *A. esculentus*, and *C. argentea* were greatly enhanced under higher light conditions as compared with its development under the shade. Higher plant heights observed in the control regimes of *A. cruentus*, *C. olitorius* and *C. argentea* implies that these plants have higher tolerance of heat compared to *A. esculentus* and *D. regia*. Light stress also had significant effect on all the growth parameters.

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