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Effects of Light and Nutrient Stress on Some Growth Parameters of Cowpea (*Vigna unguiculata* (L.) Walp)

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Abstract: Cowpea, variety Ife Brown was exposed to light and nutrient to study some growth parameters. The coefficient of variation showed that shoot height varied depending on light levels but independent of nutrient levels. Dry weight, leaf and stem biomass were dependent on light rather than nutrient. The root biomass was however found to depend largely on the light levels. There was not much variation in the number of leaflet formed in each treatment.

Key words: Light and nutrient, stress effects, growth, cowpea

Introduction

Plant growth rate is dependent on the interaction of many complex processes, which are influenced by both genetic and environmental factors. Solar radiation and temperature are important factors in the life of a plant. Light is the ultimate source of energy for virtually all life on planet earth. It regulates plant growth and development apart from its direct effect on photosynthesis. Nutrients are required in plant in adequate quantities for metabolic regulation, production of new tissues as well as development. They are structural components of metabolic and protoplasm structure. Studies have shown that low light cause reduced leaf area, number of pods, as well as seeds per pod and that a combination of low light and nutrient stress caused a delay in onset of production (Adelusi and Aileme, 1997). The onset of the reproductive phase known to be delayed by low light and low nutrient while low nutrient shortened the duration of the reproductive phase. Low light also affects the accumulation of chlorophylls and carotenoids, which in turn affects the photosynthetic rate as well as efficiency (Adelusi and Aileme, 1997). There is a balance between relative light harvesting, energy transducing and energy consuming components of the photosynthetic apparatus. A disruption of the above causes stress (Osmond *et al*., 1987). Crops grown in rich soils are known to produce shorter roots that are much branded and more compact than those grown in poor soils (Oke, 1985). The extent of the root systems was related to texture and structure of soils as well as available nutrients. An interaction between temperature, water and salt stress may be associated with photo-inhibition (Osmond *et al*., 1987). Nutrient stress can be as a result of the form in which nutrient exist; the process by which they become available to the plant; the content of the soil solution and pH (Hale and Orcutt, 1987). Since light and temperature are closely related and the developmental stages closely related to temperature over a period of time, then light has an important role to play in the developmental stages of plants. Thompson *et al*. (1988), observed that at medium irradiance and high nutrient levels, leaf expansion, chlorophyll content and photosynthesis were optimal. A plant acclimatizes to a given irradiance and nutrient availability by physiological adjustment, which serves to increase carbon gains (Thompson *et al*., 1988).

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In the present study, the effect of mineral nutrient as well as different levels of irradiance on shoot height, root length, total dry weight, leaf, stem and root biomass as well as total number of leaves were compared.

Materials and Methods

This study was carried out in the Department of Botany, Obafemi Awolowo University, Ile-Ife. Nigeria. Pure lines of Cowpea (*Vigna unguiculata*) seeds (Ife Brown Variety) were collected from the Teaching Research Farm of Obafemi Awolowo University, Ile-Ife. These were grown in a 20 cm diameter 5.5 L plastic pots that were filled with demineralized sand washed with tap water to a pH of 7. Each pot had three holes bored at the base to enhance drainage. After ten days the plants were divided into four pots containing 21 pots each made up of two light levels and two nutrient levels as follows: High Light High Nutrient (HLHN); High Light-low Nutrient (HLLN); Low Light High Nutrient (LLHN); Low Light-low Nutrient (HLLN). The low light treatments were placed under the shade of *Lagerstroemia indica* (Crepes myrtle) tree while the high light treatments were placed under direct sunlight. Light energy under the shade tree was approximately 16.74 Wm^{-2} while direct sunlight was approximately 58.70 Wm^{-2}. Mean monthly light intensity was determined using an actinometer following the method of Heinicke (1963). Plants under nutrient stress were watered once in 2 days with 100 mL of nutrient solution. Nutrient solution was prepared according to the Long Ashton Formula as modified by Hewitt (1952).

Samplings were done at weekly intervals starting from 10 days after planting. Plants were randomly picked from pots in each of the four treatments. Twenty-one plants were picked from each treatment. A transparent ruler graduated in centimeters was used accurately to measure the following parameters: shoot height, from soil top to the terminal end, root length of the main root. Total number of leaves per plant was noted and fresh weights of the plants were taken. Plants were dried at 80°C in a Gallemkamp oven until a constant weight was achieved. After cooling, the dry weights were determined. The dried samples were then separated into leaves, stems and roots and their different weights determined.

Results

Shoot height increased in both low light-high nutrient (LLHN) and Low light-low nutrient (LLLN) plants throughout the experiment (Fig. 1). The increment in shoot height stopped at pod-filling stage in both high light-high nutrient (HLHN) and high light-low nutrient (HLLN) plants. The lowest shoot height was recorded in HLLN plants. The coefficient of variation showed that the means of the treatments varied depending on light level but independent of the nutrient level (Table 1).

Root length increased in all the treatment throughout the experiment (Fig. 2). Coefficient of variation showed that root length was dependent on nutrient level rather than light level (Table 1).

Total dry weight increased gradually in all the four treatments until the flowering stage when the rate of increase became rapid (Fig. 3). The HLHN plants had the greatest amount of biomass accumulation followed by HLLN plants. The plants under shade had approximately equal biomass throughout the experiment. The difference in the means of the plant dry weight depended more on light levels than on applied nutrients (Table 1). Leaf dry weight increased in plants under high light while plants under low light had an initial decrease (Fig. 4). The increase in HLHN and HLLN plants lasted

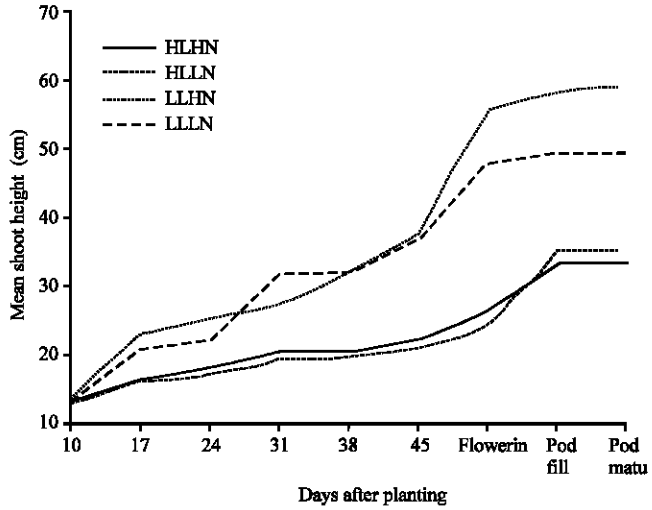

Fig. 1: Effect of light and nutrient stress on mean shoot height

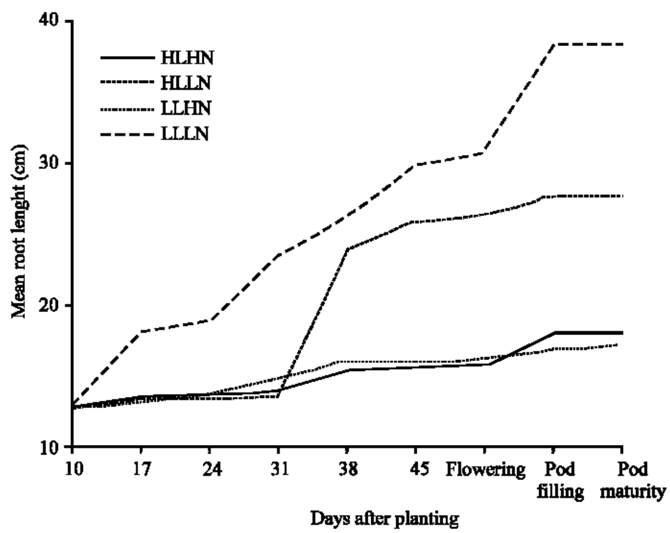

Fig. 2: Effect of light and nutrient stress on mean root height

Table 1: Coefficient of Variation (CV) in percentages showing means variation

Parameters	High light high nutrient (HLHN)	High light low nutrient (HLLN)	Low light high nutrient (LLHN)	Low light low nutrient (LLLN)
Shoot height	32.50	28.60	21.70	25.70
Root length	77.80	29.20	91.10	29.50
Plant dry weight	12.70	12.70	14.40	14.30
Leaf dry weight	15.00	17.40	23.30	22.80
Stem dry weight	15.10	16.10	15.70	17.20
Root dry weight	19.00	18.00	46.60	28.30
No. of leaflet per plant	26.30	29.80	26.00	25.90
Leaf area	16.90	17.70	19.30	16.30

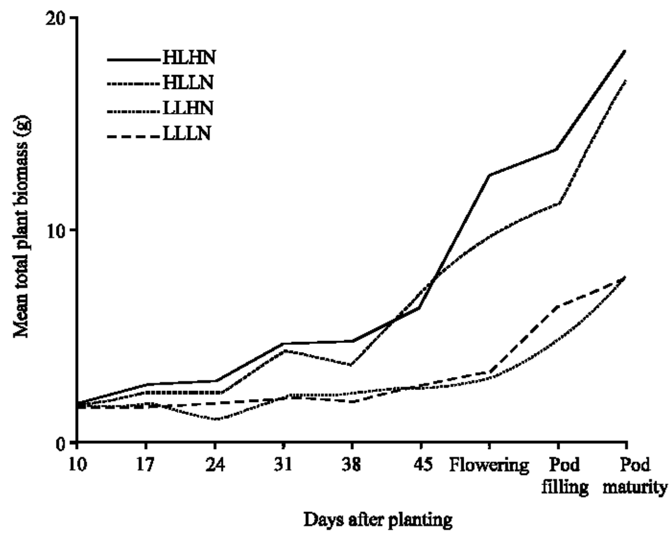

Fig. 3: Effect of light and nutrient stress on mean total plant biomass

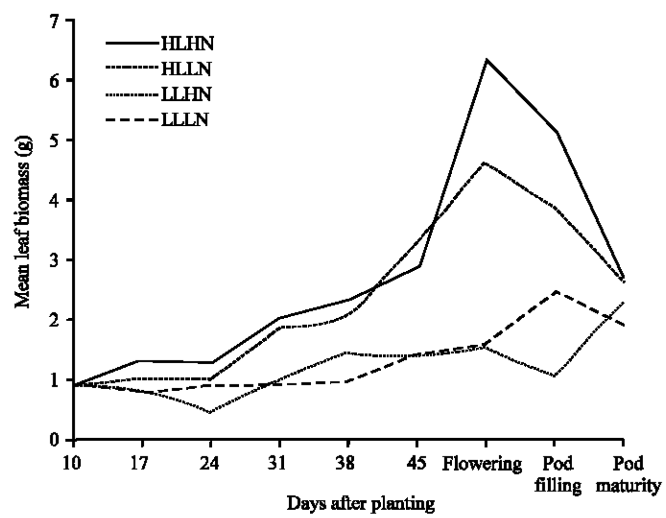

Fig. 4: Effect of light and nutrient stress on mean leaf biomass

till the flowering period followed by a decrease till the end of the experiment. The increase in leaf biomass lasted till the pod filing stage in LLLN plants while that of LLHN had a drop between the flowering and pod-filling stage followed by an increase. Leaf dry weight was more dependent on light than on nutrient (Table 1).

Stem biomass was approximately equal in both HLHN and HLLN plants till the flowering period followed by a decrease that lasted till the end of the experiment (Fig. 5).

Stem biomass was approximately equal in LLHN and LLLN plants throughout the period of the experiment. There was not much variation in the treatment means (Table 1). The nutrient-stressed

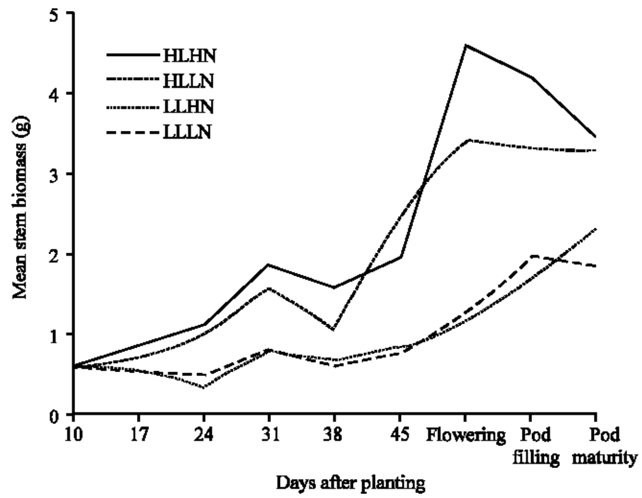

Fig. 5: Effect of light and nutrient stress on mean stem biomass

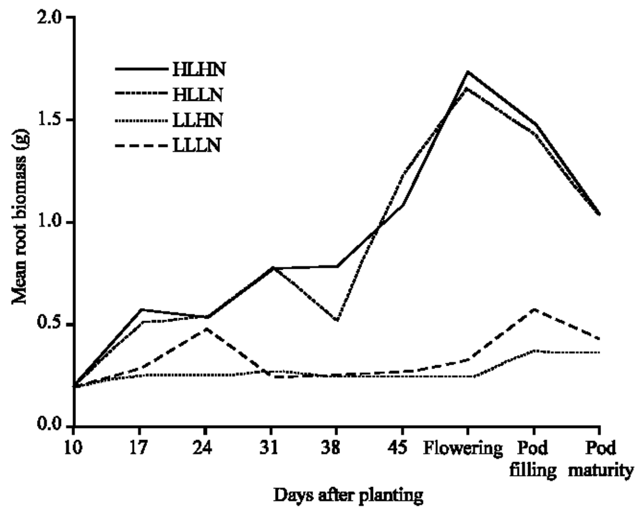

Fig. 6: Effect of light and nutrient stress on mean root biomass

plants in both sunlight and under shade had means that were closer than the nutrient stressed plants also in both light shade (Table 1).

Both dry weight increased throughout the experiment until the flowering period when there was a decrease (Fig. 6). Root biomass was approximately equal in the HLHN and HLLN plants throughout the experiment. The degree of variability in the root biomass was dependent on the light levels. The means of plants under shade varied from those of plants under full sunlight (Table 1).

Total number of leaves increased after the 24th and 17th day in plants under sunlight and shade respectively. Leaf formation stopped with the onset of flowering in plants under sunlight while it continued to pod-filling stage in plants under shade (Fig. 7). Plants under shade had longer internodes, smaller leaflets, which were thinner but were numerous. Rate of abscission was also higher in plants

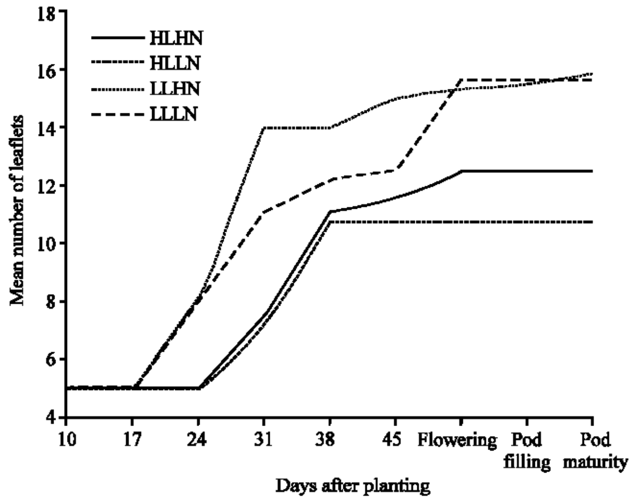

Fig. 7: Effect of light and nutrient stress on mean number of leaflets

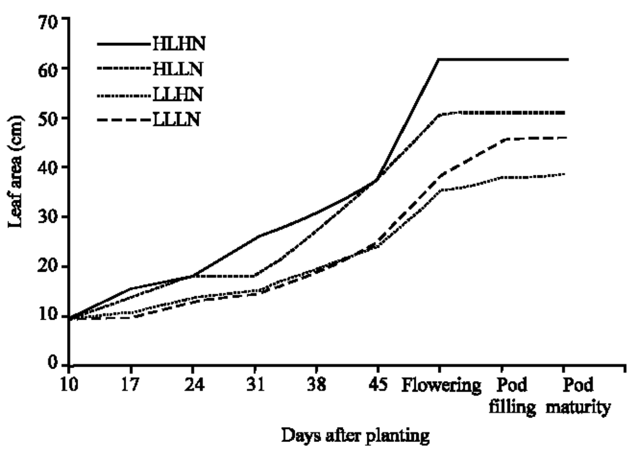

Fig. 8: Effect of light and nutrient stress on leaf area

under sunlight. The LLHN plants had the greatest number of leaflets, followed by LLLN while HLLN plants produced the lowest number of leaflets.

The coefficients of variation table showed that the number of leaflets formed in each treatment do not actually vary (Table 1).

Leaf area increased gradually in all the treatments until the pod-filling stage (Fig. 8). This decreased slightly towards the end of the experiment. The leaf area of HLHN plants was highest followed by that of HLLN while LLHN had the lowest leaf area. The variation of the means of the leaf area was however negligible (Table 1).

Discussion

The observed higher plant height in the shade and a change in plant habit from erect to trailing condition agrees with the results of Hoddinot and Hall (1981), Vince Prue (1975) and Thomas and

Raper Jr. (1983). Plants growing in low light condition respond to light stress by devoting more of their available carbon to shoot growth resulting partly in taller stems in search of more light. Apical dominance is also demonstrated in cowpea plants under shade (Thomas and Raper Jr, 1983). The higher shoot height in LLHN plants was due to the devotion of their nutrient to stem extension and apical dominance, Morgan and Smith (1981), found in *Chenopodium album* that stem extension under shade was due to reduced red to far-red light ratio. Stem extension was not favoured in high light condition due to red to far-red light ratio. Among plants under high light treatment, HLHN had a greater shoot height due to the fact that in plants with low nutrient supply, extra carbon required for root growth is obtained from non-assimilatory tissues especially the stem (Peace and Grubb, 1982).

Plants adapt to nutrient stress by increasing root growth relative to leaf area (Chung *et al*., 1982). The above accounted for the greater root length in the nutrient stressed plants in high light as well as low light treatments. Thompson *et al*. (1988), found root growth to be enhanced at low levels of low nutrient supply particularly under high light condition. Enriched soil promotes a better shoot development with roots that are less branching and less compact (Oke, 1985). Nutrient-stressed plants had more nodules whether under high or low light confirming the fact that application of nutrient nitrogen reduced the nodulation of cowpea plants because of the adequate supply of nitrogen from the nutrient-nitrogen at the expense of that fixed by symbionts. Nodules formed under low light were fewer because the plants tend to conserve their carbon at the expense of symbionts (Summerfield *et al*., 1976).

Observed higher biomass (dry matter yield) under the high light condition can be attributed to optimal rate of photosynthesis, greater leaf surface area and higher chlorophyll content. Leaves in high light condition retain a relatively high photosynthetic capacity irrespective of the nutrient level. Adequate nutrient supply increased the dry matter production in high light condition, a situation that substantiate the findings of Peace and Grubb (1982) and Thompson *et al*. (1988) that higher dry weight was attributed to optimal leaf expansion rates. Though nodulation is supposed to favour the accumulation of plant biomass in plants with low nutrient, part of the carbon is lost to symbionts and therefore the reduction in dry weight. The increase in dry matter in plants under high light was due to the fact that these plants intercepted more radiation than those under shade (Monteith, 1972; Pandy and Sinha, 1979; Patterson, 1980, 1982).

The biomass partitioned to the different plant parts shows that the leaves had the greatest dry weight under both high light and low light conditions while the root was lowest. The greater leaf weight in high light can be attributed to the production of thicker leaves with reduced spongy mesophyll cell volume and thicker palisade tissue and increased stomatal carbon dioxide conductance (Jurik *et al*., 1982; Thompson *et al*., 1988). Light also increased the transfer of photosynthate to sink development and assimilation rate is higher under the sun leading to an overall increase in leaf growth (Boardman, 1977).

Nutrient stress affects mesophlly cells development and so affects photosynthesis (Osmond, 1983). The effect of low nutrient on leaf development is low under low light treatment because the major influence on sink activity is high light (Thompson *et al*., 1988).

The lowering of the stem biomass under low light is not unconnected with the reduction in the production of photosynthate. However, low nutrient also contributed to the lowering of stem biomass as more carbon was diverted to root growth from both stem and leaf tissues (Peace and Grubb, 1982). The HLHN and the LLHN plants had more stem component than the HLLN and LLLN plants respectively as the soil was enriched with nutrient supply and so vigorous root growth was not necessary.

Plants under shade were able to grow vegetatively with maximum leaf production. The direct effect of light on temperature, that is, high light intensity, means that high temperature can lead to a decrease in node production in cowpea (Summer field *et al*., 1976). Imire and Butler (1983) found that low temperature and photoperiod leads to production of more leaves in low light conditions in cowpea. Singh (1978) reported that in spring barley, reduced light intensity decreased leaf number but increased leaf area. In peanut, Katring (1979) however found leaf number to the equal at both low and high light intensity but the former had larger leaf surface area indicating a shift in assimilating partitioning in response to low light. The production of more leaves under the shade condition may be a mechanism evolved by cowpea plants to increase total surface area for photosynthesis due to reduced leaf area. Nutrient stress in high light as well as low light led to a reduction in the number of leaves produced due to the fact that the extra carbon needed for greater root growth as a result of low nutrient supply was taken from their non-assimilating tissue as well as leaf tissue (Peace and Grubb, 1982) which led to stem component production being proportionately less in nutrient stressed plants. Plants are known to adapt to nutrient stress by increasing root growth relative to leaf area (Chung *et al*., 1982).

Parameters like shoot height, plant biomass, were all found to be affected by light as well as nutrient stress in the present study and could be used as dependable characters to monitor both light and nutrient stress in cowpea plants.

References

Adelusi, A.A. and J.D. Aileme, 1997. Effect of light and mineral nutrient stress on the yield and yield components of cowpea (*Vigna unguiculata*). Nig. J. Bot., 10: 1-6.

Boardman, N.K., 1977. Comparative photosynthesis of sun and shade plants. Ann. Rev. Plant Physiol., 28: 355-377.

Chung, G.C., R.N. Rowe and R.J. Field, 1982. Relationship between shoot and roots of cucumber plants under nutritional stress. Ann. Bot., 50: 859-861.

Hale, M.G. and D.M. Orcutt, 1987. The Physiology of Plants Under Stress. John Wiley and Sons Inc. NY. Chichester. Brisbane.

Heinicke, D.R., 1963. The microclimate of fruit trees, I. Light measurement with urinal oxalate actinometer. Can. J. Plant Sci., 43: 561-568.

Hewitt, E.G., 1952. Sand and Water culture methods used in the study of plant nutrient. Commonwealth Bureau Horticultural Plantation Crop. (Gr. Brit.) Technical Communication, 22.

Hoddinot, J. and L.M. Hall, 1982. The responses of photosynthesis and translocation rate to changes in the ratio of light. Can. J. Bot., 60: 1285-1291.

Imire, B.C. and K.L. Buttler, 1983. Joint contribution of individual attribute to seed yield of cowpea (*Vigna unguiculata)* in small plots. Field Crops Res., 6: 161-170.

Jurik, T.W., J.R. Chabot and B.F. Chabot, 1982. Effects of light and nutrient on leaf size, carbon dioxide exchange and anatomy of wild strawberry (*Fragaria virginata)*. Plant Physiol., 70: 1044-1048.

Katring, D.L., 1979. Light effects on development of an indeterminate plant. Plant Physiol., 64: 665-667.

Monteith, J.L., 1972. Solar radiation and productivity in tropical ecosystems. J. Applied Ecol., 9: 747-766.

Morgan, D.C. and H. Smith, 1981. Control of development in *Chenopodium album*. L. by shade light. The effect of light quantity (total fluence rate) and light quality (red:far red ratio). New Phytol., 88: 239-248.

Oke, S.O., 1985. Effect of soil texture, nutrient stress and water stress on yield of *Andropogon gayanus*. Knuth and *Schizchyrium sanguineum* (Rertz) Alston. Unpublished M.Sc. Thesis, University of Ife (now Obafemi Awolowo University), Nigeria.

Osmond, C.B., 1983. Interactions between irradiance, nitrogen nutrition and water stress in sunshade responses of *Solanum dulcamara*. Oecologia, 57: 316-321.

Osmond, C.B., M.P. Austin, J.A. Berry, W.D. Billings, J.S. Boeyr, J.W.H. Dacey, P.S. Nobel, S.D. Smith and W.E. Winner, 1987. Stress physiology and distribution of plants. Bioscience, 37: 33-47.

Pandy, B.N. and R.P. Sinna, 1979. Light as a Factor of Growth and Morphogenesis II. Effect of varying photoperiods on *Crotalaria juncea*. L. and *C. servica* Retz. New Phytologist, 38: 395-400.

Patterson, D.T., 1980. Shading effect on growth and partitioning of plant biomass on Congo grass (*Imperata cylindrica*) from shaded and exposed habitat. Weed Sci., 28: 735-740.

Patterson, D.T., 1982. Shading responses of purple and yellow nutsedges (*Cyperus rotundis* and *C. esculentus*). Weed Sci., 30: 25-30.

Peace, W.J.H. and P.J. Grubb, 1982. Interraction of light and mineral nutrient supply in the growth of *Impatients parviflora*. New Phytol., 90: 127-150.

Singh, B.G., 1978. Effect of shade on the growth of spring barley. Qyton, 36: 53-60.

Summerfield, R.J., H.C. Wien and F.R. Minchin, 1976. Integrated field and glasshouse screening for environmental sensitivity in cowpea (*Vigna unguiculata*) Exp. Agric., 12: 241-248.

Thomas, J.F. and C.D. Raper Jr, 1983. Photoperiod effects on soyabean growth during the onset of reproductive development under various temperature regimes. Botanical Gazette, 144: 471-476.

Thompson, W.A., G.C. Stocker and P.E. Kriedemann, 1988. Growth and Photosynthetic Response to Light Nutrients of *Flindersia brayleyana*. F. Muell, a Rainforest Tree with Broad Tolerance to Sun and Shade in Ecology of Photosynthesis in Sun and Shade. Eds., Evans J.r., von Caemmerer and S. Adams 111. W.W., pp: 299-315.

Vince-Prue, D., 1975. Phototropism in Plants. McGraw Hill, N.Y. London.