

EFFECTS OF NUTRIENT AND LIGHT STRESS ON SOME MORPHOLOGICAL PARAMETERS OF TOMATO (*LYCOPERSICUM ESCULENTUM* MILL)

Okunlola, G.O. and Adelus, A.A.

Department of Botany, Obafemi Awolowo University, Ile Ife, Osun state, Nigeria

lanrog01@yahoo.com

(Received: August 2012; Accepted: October 2012)

ABSTRACT

Tomato seedlings were subjected to light and nutrient stress to determine the effects of each of these stress factors as well as their combined effects on some morphological parameters of the plant. A two-way Analysis of Variance (ANOVA) carried out on the data obtained showed that light produced significant effect on all the parameters measured except on the shoot height. Nutrient however did not produce any significant effect on any of the morphological parameters measured. There was also no significant interactive effect of light and nutrient on the morphological parameters measured.

Key words: Stress, Light, Nutrient, Morphology, *Lycopersicum*.

INTRODUCTION

The term stress is used for any factor that is potentially unfavourable to plant and stress resistance is used for the ability of the plants to survive the unfavourable factor. The response of plants to stress conditions differs among cultivars, within species, and among stages of plant development within a cultivar. The response reflects differences in area of adaptation and in the biological mechanisms that have evolved for coping with adverse environments.

To produce a good yield, it is important that all the environmental factors should be at optimal levels. Under natural conditions, plants frequently encounter combinations of stress factors (Bazzaz, 1996; Sultan *et al.*, 1998). Consequently, the individual ability to tolerate multiple stresses through morphological adjustments is a major feature that determines species survival and colonization, and hence the ecological breadth of the species (Chapin *et al.*, 1987; Bazzaz, 1996; Sultan *et al.*, 1998). Light plays a critical role in plant growth and development. The quantity and quality, as well as direction of light, are perceived by photosensory systems which, collectively, regulate plant development, presumably to maintain photosynthetic efficiency (Hangarter, 1997). Photo-oxidative damage, i.e. light dependent generation of reactive oxygen species (ROS) in chloroplasts, is the key process involved in cell damage and cell death in plants exposed to environmental stress factors (Foyer *et al.*, 1997; Asada 2000; Foyer and Noctor, 2005).

Of all the mineral nutrients, nitrogen plays a major

role in the utilization of absorbed light energy and photosynthetic carbon metabolism (Huang *et al.*, 2004). An excess of non-utilized light energy can be expected to occur in N-deficient leaves. In standing water, when exposed to increasing nutrient stress, plants tend to have a reduced total dry matter and leaf number (Zhang 1996; Crossley *et al.*, 2002), increased allocation to root and stem and decreased allocation to leaves (Gedroc *et al.*, 1996; Madsen and Cedergreen, 2002), reduced water content of organs (Ryser, 1996; Craine *et al.*, 2001), reduced leaflet number per leaf and reduced specific leaf Area (SLA; Li *et al.*, 1999). These traits correspond to adaptations usually observed in nutrient-poor habitats. Like nitrogen deficiency, deficiencies of Potassium, Magnesium and Zinc also enhance the sensitivity of plants to photo-oxidative damage. When supplies of these nutrients are low, leaf symptoms of chlorosis and necrosis, and disturbances of plant growth become more severe when plants are exposed to high light intensity (Marschner and Cakmak, 1989; Cakmak and Marschner, 1992; Polle, 1996). The form in which Nitrogen is supplied affects plant tolerance to photo damage.

Tomatoes are now eaten freely throughout the world, and their consumption is believed to benefit the heart among other things. Lycopene, one of nature's most powerful antioxidants, is present in tomatoes, especially when cooked. Tomatoes have been found to be beneficial in preventing prostate cancer. Its extract, branded as Lycomato, is now also being promoted for treatment of high blood pressure. Tomato has an acidity level which makes it easy to preserve in

home canning as tomato sauce or paste. Unripe green tomatoes can also be breaded and fried, or pickled.

A better understanding of the environment is important for plant growth and reproduction. The ability of Man to modify the environment so as to obtain more favourable plant growth and yield is equally important. To anticipate the problems that may be encountered in expanding the growth of tomato, it is very important to study the factors that will adversely affect production or favour increased yield. The effect of stress factors on plant growth processes are numerous and may be due to the interaction of these factors. The objectives of the research are therefore to determine the effect of light and nutrient stress on the plant growth and also to study some of the morphological changes that occur in tomato in response to light and nutrient stress.

MATERIALS AND METHODS

Seedlings of *Lycopersicon esculentum* (Ife No 1 Variety) were utilized in the experiment. The sand that was used for the experiment was collected on the campus of Obafemi Awolowo University Ile-Ife, Nigeria. The sand was soaked in 1N Hydrochloric acid for one hour to solubilize mineral elements and eliminate microbes which might be present in it. At the end of this period, the acid was drained off and the sand was washed with tap water and then distilled water until the pH of the decantable water was between 6 and 7. The washed sand was air-dried and transferred into sixty 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 depth and 24 cm in diameter were filled near brim with the sand.

The seeds were planted in the pots containing the washed sand. Ten seeds were planted in each pot and after germination, these were thinned to four. The seedlings were watered daily with 100ml of distilled water in the morning and 100ml of distilled water in the evening until they were fully established. The established seedlings were raised under direct natural sunlight before the experiment commenced.

On the fifteenth day after planting, the pots were divided into four groups each containing fifteen pots, each pot containing four seedlings. Groups 1

and 2 were made to receive direct sunlight by placing them in the open space beside the Department of Botany, Obafemi Awolowo University, Ile-Ife, while groups 3 and 4 were placed under the shade provided by the *Tecoma stans* tree beside the Department of Botany, Obafemi Awolowo University. The intensities of light in both the open space and the shade were measured with a digital lux meter TCX100. An average of 16300 lux of light was obtained in the shade while an average of 48400 lux was obtained under the full sunlight. From the fifteenth day of the experiment, Groups 1 and 3 received 100 ml of complete nutrient solution everyday while groups 2 and 4 also received 100 ml of complete nutrient solution but only once every four days. The seedlings in all the four groups received 100ml of distilled water everyday.

Sampling was carried out at weekly intervals, starting from fifteenth day after planting to the 78th day. Plants were randomly picked from the pots in each of the four treatments. Three replicates were used for each parameter. The four treatments were tagged: Full sunlight with full nutrient supply (FLFN) for group 1 plants; Full sunlight with partial nutrient supply (FLPN) for group 2 plants; Partial sunlight with full nutrient supply (PLFN) for group 3 plants and Partial sunlight with partial nutrient supply (PLPN) for group 4 plants. 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 total number of leaves per plant was counted and recorded. For the fresh weight determination, plants were carefully uprooted and the soil attached to the roots washed off with tap water. The fresh weight of plant was then taken on a weighing balance after which it was dried in a Gallenkamp oven at 80°C until a constant weight was achieved. After cooling, the dry weight was determined. The dried samples were then separated into leaves, stems and roots and their different weights were determined.

RESULT

The shoot height of the tomato plants in the different light and nutrient treatments is as shown in Figure 1. The shoot height of plant in all the treatments increased from the beginning of the experiment to the end. At the end of the experiment, the PLFN plants recorded the

highest shoot height, followed by the PLPN plants while the FLPN plants recorded the lowest shoot height. There was no significant effect of light and also of nutrient on the shoot height of tomato plants ($P>0.05$). There was also no significant interactive effect of light and nutrient on the shoot height ($P>0.05$).

There was an increase in the number of leaves in the tomato seedlings grown under the different light and nutrient treatments as shown in Figure 2. At the end of the experiment, the FLPN plants recorded the highest number of leaves, followed by the FLFN plants while the PLFN plants recorded the lowest number of leaves. There was a significant effect of light on the number of tomato leaves ($p < 0.05$). There was however, no significant effect of nutrient on the number of tomato leaves as well as any significant interactive effect of light and nutrient stress on the number of tomato leaves ($p > 0.05$).

The total biomass, leaf biomass, shoot biomass and root biomass of plants under the shade and the full sunlight showed similar patterns as can be seen in Figures 3, 4, 5 and 6. In other words, the pattern of FLFN and FLPN plants are similar in each case while the pattern of PLFN and PLPN plants are also similar in each case. The same thing

was applicable to leaf biomass, shoot biomass and root biomass. In all the above, the FLPN plants recorded the highest biomass for a greater part of the experimental period. There was a significant effect of light on the total biomass, leaf biomass, shoot biomass and root biomass ($P > 0.05$). Nutrient however did not have significant effect on the total biomass, leaf biomass, shoot biomass and root biomass ($P > 0.05$). There was also no significant interactive effects of light and nutrient on the above mentioned parameters ($P>0.05$).

The plants in the full sunlight started producing fruits from the 36th day of the experiment. Approximately equal numbers of fruits were produced from the 43rd day to the end of the experiment in the FLFN and FLPN plants. However, from the beginning to the end of the experiment, no single flower was found on the plants in the shade (PLFN and PLPN) irrespective of the different levels of nutrient applications. Consequently, there was no fruit formation on the plants throughout the experimental period. Light had a significant effect on the number of fruits ($p < 0.05$). However, nutrient had no significant effect on the number of fruits ($P > 0.05$). There was also no significant interactive effect of light and nutrient on the number of fruits ($p > 0.05$).

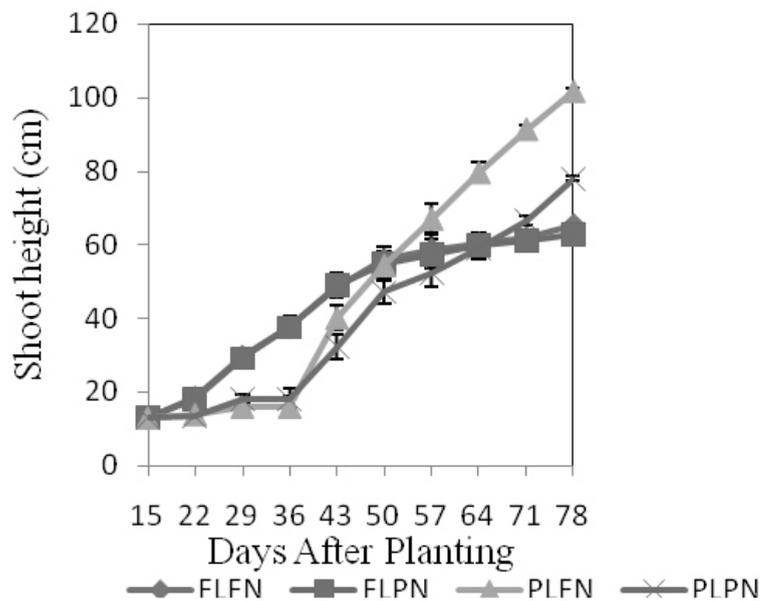


Fig.1: Shoot Height of Tomato Grown under Different Light and Nutrient Treatments.

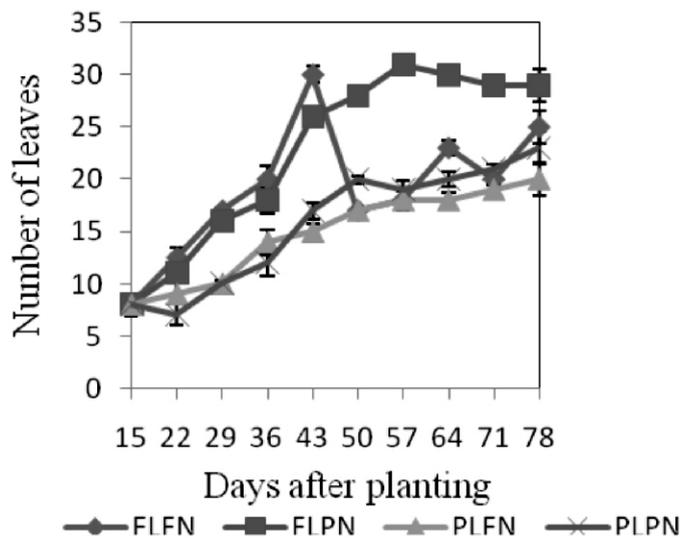


Fig. 2: Number of Leaves of Tomato Grown under Different Light and Nutrient Treatments.

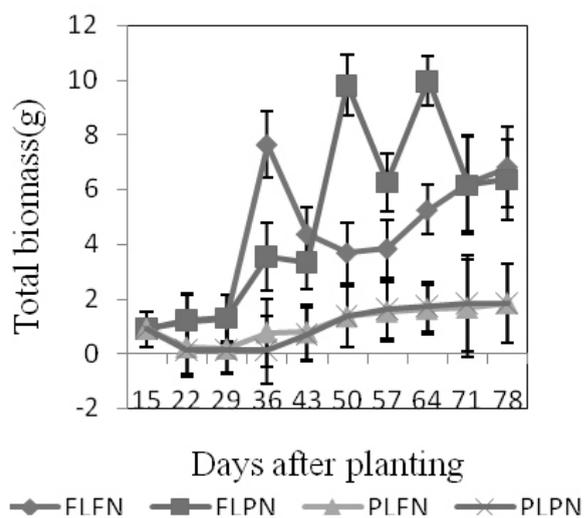


Fig. 3: Total Biomass of Tomato Grown under Different Light and Nutrient Treatments

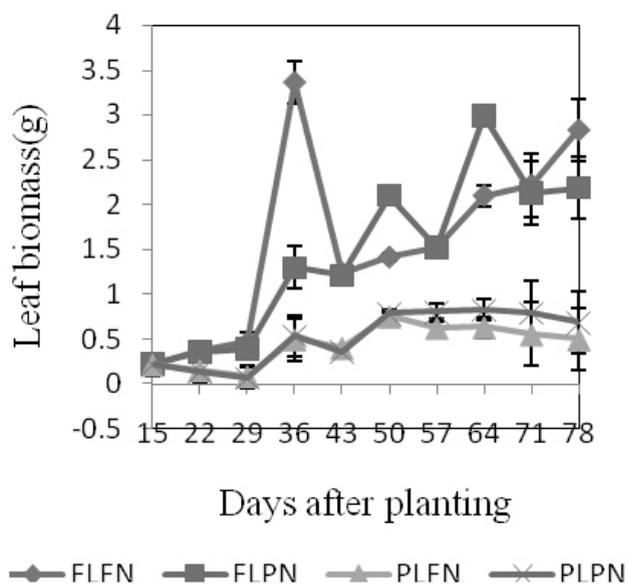


Fig.4: Leaf Biomass of Tomato Grown under Different Light and Nutrient Treatments

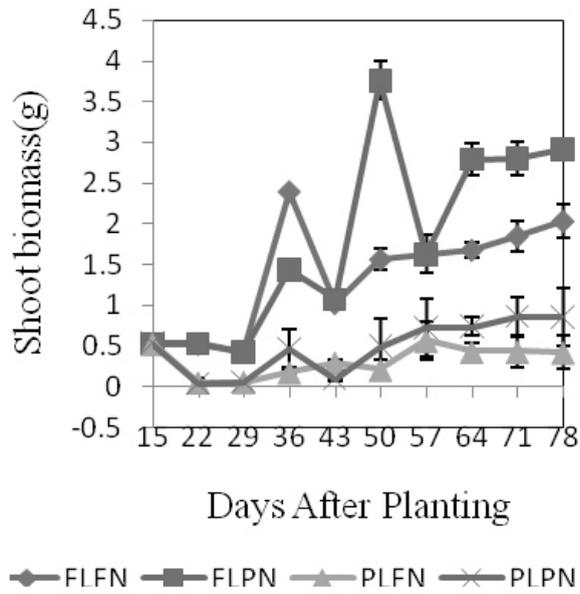


Fig. 5: Shoot Biomass of Tomato Grown under Different Light and Nutrient Treatments

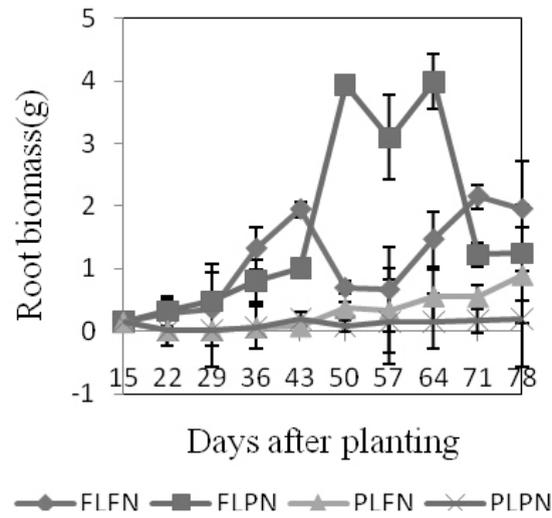


Fig. 6: Root Biomass of Tomato Grown under Different Light and Nutrient Treatments

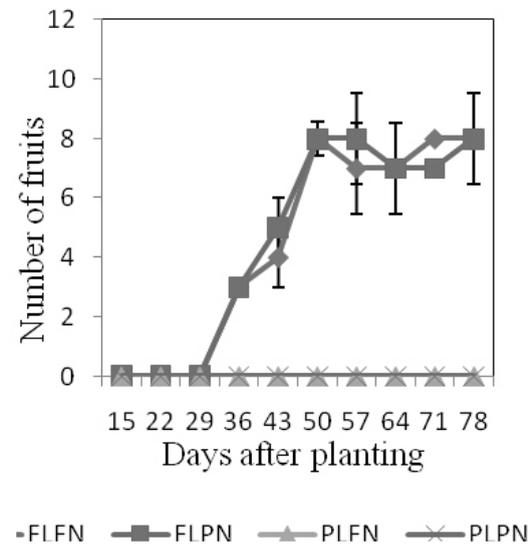


Fig. 7: Number of Fruits of Tomato Grown under Different Light and Nutrient Treatments

Results of Duncan Multiple Range Test (DMRT) for the Parameters Measured.

Treatments	Shoot Height	Number of Leaves	Plant Biomass	Leaf Biomass	Shoot Biomass	Root Biomass	Number of Fruits
FLFN	46.033a	13.11a	3.752a	1.275a	1.351a	1.119a	3.391a
FLPN	43.421a	13.45a	3.251a	1.213a	1.209a	1.041a	3.399a
PLFN	45.531a	15.04b	2.034b	0.754b	0.774b	0.553b	1.119b
PLPN	44.367a	15.87b	1.902b	0.730b	0.619b	0.461b	1.149b

Values in the same column with different letters are significantly different at $P < 0.05$

DISCUSSION

In this study of the effect of light and nutrient stress on some morphological parameters of *Lycopersicon esulentum*, 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 and others to nutrient stress while others were exposed to both light and nutrient 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 or nutrient stress or a combination of both light and nutrient stress that were introduced during the experiment.

The observed higher plant height in the shade agreed with the result of Warrington *et al.*, (1998) and Ninemetes (1999) who found typical morphological response under conditions of low photo flux density (PFD) as an increase in stem elongation and a reduction in leaf dry mass per area. Under low light intensity, plants generally bear longer internodes and are less tough and more succulent than those in intense light (Barber and Anderson, 1992). The survival of the plants under the shade depends on the efficiency with which they capture and utilize light. According to Weiner *et al.* (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. The plant height and internode length decreased as the light intensity increased. These results are in agreement with the results of Mortensen and Larsen (1989), who observed a decrease in shoot length of *Nepbrolepis exaltata* L. at high light intensity. According to Dudeck and Peacock (1992), low irradiance results in increased stem elongation, longer leaf sheaths, higher chlorophyll

content and higher leaf succulence in turfgrass.

In full sunlight, plants usually have higher leaf area and higher chlorophyll content and therefore higher rate of photosynthesis. Light is known to be the ultimate substrate for photosynthetic energy conversion. According to Mc Donald *et al.* (1992), growth at higher irradiance generally leads to enhanced nutrient efficiency, that is, greater biomass production per unit biomass investment. They found that light and nutrient interactions were significant for Relative Growth Rate and Net Assimilation Rate, implying that growth was more responsive and more strongly limited by nutrient at higher light. This greater plant biomass of the plants in the sunlight compared to those of the plants under the shade, however, contradicted the findings of Poorter and Van der werf. (1999) who found that dry weight of herbaceous plants, like pepper and tomato, decreases with increasing light intensity. Leaves in the full sunlight retained a relatively high photosynthetic rate irrespective of the nutrient level.

Since irradiance directly affects the photosynthetic source supply, there might be a resultant reduction in supply to sink under low light conditions resulting to a lower dry matter accumulated in the stem and roots of the plants in the shade when compared with those in the full sunlight. According to Jurik (1991), the leaves of plants in full sunlight are usually thicker with reduced mesophyll cell volume and thicker leaf palisade tissue and increased stomatal carbon dioxide conductance which usually leads to an overall increase in leaf dry weight.

Light plays a decisive role in morphogenesis and resource allocation pattern in plants. The higher shoot dry weight in the plants in the full sunlight compared to those under the shade was in agreement with the findings of Robin *et al.* (1992) who reported a morphogenetic response of clover to changes in light quality in the form of an

increase in the proportion of carbon allocated to shoot tissues associated with 'light foraging'. This decreased the C available for root growth. This was due to an allocation of more dry matter to vegetative than reproductive structures with lower light intensity. Generally, the plant species evaluated in this study showed a decrease in assimilate allocation to root and reproductive parts of the plants in response to reduced light availability, which is also the typical strategy of plants adapting to shade. Similar adjustments in response to reduced light have been reported in soybean, lambsquarters, velvetleaf, eastern black nightshade, and tumble pigweed (Stoller and Myers, 1989). Allard *et al.* (1991) reported a reduction in dry matter for tall fescue under reduced irradiance relative to plants under high irradiance. It is well established that shaded plants allocate much of their photosynthates into the shoot structures to allow for interception of more light.

Conclusively, the growth of *Lycopersicon esculentum* used for this study was greatly enhanced under full sunlight when compared with that under the shade. Decreased irradiance however favoured shoot height. Nutrient levels did not produce any significant effect on any of the parameters studied.

REFERENCES

- Allard, G., Nelsonk, C.J. and Pallardy S.G. 1991. Shade effects on growth of tall fescue. I. Leaf anatomy and dry matter partitioning. *Crop Science*, 31: 163-167.
- Asada, K. 2000. The water-water cycle as alternative photon and electron sinks. *Physiological Transactions of Royal society*, B.335: 1419- 1430
- Barber, J. and Anderson, B. 1992. Too much a good thing: light can be bad for photosynthesis. *TIBS* Feb 17: 61-66.
- Bazzaz, F.A. 1996. *Plants in changing environments: linking physiological, population and community ecology*. Cambridge: Cambridge University Press.
- Cakmak, I. and Marschner. (1992). Magnesium deficiency and high light intensity enhance activities of superoxide dismutase, ascorbate peroxidase and glutathione reductase in bean leaves. *Plant Physiology* 98: 1222-1227.
- Chapin, F.S., Bloom, A.J., Field C.B. and Waring, R.H. 1987. Plant responses to multiple environmental factors. *Bio Science* 37:49-57.
- Craine, J.M., Froehle, J., Tilman, D.A., Wedin, F.S. and Chapin. 2001. The relationships among root and leaf traits of 76 grassland species and relative abundance along fertility and disturbance gradients. *Oikos* 93: 274-285.
- Crossley, M.N., Dennison, W.C., Williams, R.R. and Wearing, A.H. 2002. The interaction of water flow and nutrients on aquatic plant growth. *Hydrobiologia* 489:6370
- Dudeck, A.E. and Peacock, C.H. 1992. Shade and turfgrass culture. In D.V. Waddington *et al.* (ed.) *Turfgrass*, Agron, Monogr, 32, ASA, CSSA, and SSSA, Madison, WI.
- Foyer, C.H. and Noctor. 2005. Oxidant and antioxidant signaling in plants: a reevaluation of the concept of oxidative stress in a physiological context. *Plant cell and environment* 28:1056-1071.
- Foyer, C.H., Lopez-Delgado, H., Dat, J.F. and Scot, I.M. 1997. Hydrogen peroxide and glutathione associated mechanisms of acclamatory stress tolerance and signaling. *Plant Physiology* 100: 241-254.
- Gedroc, J.J., McConnaughay, K.D.M. and J.S. Coleman., 1996. Plasticity in root/shoot partitioning: optimal, ontogenetic, or both? *Functional Ecology* 10:44-50.
- Hangarter, 1997. Gravity, light and plant form. *Plant, Cell and Environment* 20: 796-800.
- Hirose, T. Werger, M.J.A. 2005. Canopy structure and photon flux partitioning among species in a herbaceous plant community. *Ecology* 76: 46-474
- Huang, Z.A., Jiang, D.A., Yang, Y., Sun, J.W. and Jin, S.H. 2004. Effects of Nitrogen deficiency on gas exchange, chlorophyll fluorescence, and antioxidant enzymes in leaves of rice plants. *Photosynthesis* 42: 357-364
- Jurik, T. W. 1991. Population distributions of plant size and light environment of giant ragweed (*Ambrosia trifida* L.) at three densities. *Oecologia* 87: 539-550.
- Li, B., Suzuki, J.I. and Hara, T. 1999. Competitive ability of two Brassica varieties in relation to biomass allocation and morphological plasticity under varying nutrient

- availability. *Ecological Research* 14: 255-266.
- Madsen, T.V. and Cedergreen, N, 2002. Sources of nutrients to rooted submerged macrophytes growing in a nutrient-rich stream. *Freshwater Biology* 47:283-291.
- Marschner, H. and Cakmak, I. 1989. High light intensity enhances chlorosis and necrosis in leaves of Zinc, potassium and Magnesium deficient bean (*Phaseolus vulgaris*) plants. *Journal of Plant Physiology* 134: 308-315.
- McDonald, A.J., Lohammer, S.T and Ingestad, T. 1992. Net assimilation rate and shoot area development in birch (*Betula pendula* Roth.) at different steady-state values of nutrition and photon flux density. *Trees: Structure and Function* 6: 16.
- Mortensen, L.M and Larsen, G.1989. Effects of temperature and light quality on growth of six foliage plants. *Scientica Hort.* 39:149-159
- Ninemetes, U. 1999. Energy requirement for foliage formation is not constant along canopy light gradients in temperate deciduous trees. *New Phytologist* 141: 459-470.
- Polle, A. 1996. Mehler reaction: friend or foe in photosynthesis? *Botanica Acta* 109: 84-89
- Poorter, H. and Van Der Werf, A.1998. Is inherent variation in RGR determined by LAR at low irradiance and by NAR at high irradiance? *A review of herbaceous species*. pp 309-336. In: Lambers, H., *et al.* (eds.) *Inherent variation in Plant Growth. Physiological Mechanisms And Ecological Consequences*. Backhuys Publishers, Leiden.
- Robin, C., Varlet-Grancher, C., Gastal, F., Flene, F. and Guckert, A. 1992. Photomorphogenesis of white clover (*Trifolium repens* L.) phytochrome mediated effects on ¹⁴C-assimilate partitioning. *European Journal of Agronomy* 1: 235-240.
- Ryser, P. 1996. The importance of tissue density for growth and life span of leaves and roots: a comparison of five ecologically contrasting grasses. *Functional Ecology* 10: 717-723.
- Stoller, E.W. and Myers, R.A. 1989. Response of soybean (*Glycine max*) and four broad weeds to reduced irradiance. *Weed Science* 37: 570-574
- Sultan S.E., Wilczek, A.M., Bell, D.L. and Hand, G. 1998. Physiological response to complex environments in annual *Polygonum* species of contrasting ecological breadth. *Oecologia* 115: 564-578.
- Warrington I.J., Rook, D.A., Morgan, D.C. and Turnbull, H.L. 1998. The influence of simulated shadelight and daylight on growth, development and photosynthesis of *Pinus radiata*, *Agathis australis* and *Dacrydium cupressinum*. *Plant Cell and Environment* 11: 343-356.
- Weiner, J.G., Berntson, M. and Thomas, S.C. 1990. Competition and growth form in a woodland annual. *Journal of Ecology* 78: 459-469.
- Zhang, J. 1996. Interactive effects of soil nutrients, moisture and sand burial on the development, physiology, biomass and fitness of *Cakile dentata*. *Annals of Botany* 78: 591-598