EFFECT OF DIFFERENT REDUCED LIGHT LEVELS ON THE MORPHOLOGY, PHYSIOLOGY AND YIELD OF FOUR SELECTED VINE CROPS

A THESIS

BY

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DEDICATED
TO
My Late Father, Ahsan Ullah
Whose memory still inspires me-

THESIS ABSTRACT

EFFECT OF DIFFERENT REDUCED LIGHT LEVELS ON THE MORPHOLOGY, PHYSIOLOGY AND YIELD OF FOUR SELECTED VINE CROPS

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A study was carried out through four separate experiments at the farm of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur. Four vegetables (i.e. cucumber, ash gourd, sponge gourd and yard long bean) were included in separate experiments. The objective of this study was to investigate the morpho-physiological changes and yield performance of these summer vegetables under four different levels of light (100, 75, 50 and 25% PAR).

In studied vegetables some of the morphological characters like main stem length, internode length, and individual leaf area increased, whereas main stem diameter and numbers of leaves per plant decreased due to the reduced light levels. At 50% PAR number of leaves per plant did not decrease significantly in cucumber and yard long bean but in ash gourd and sponge gourd leaves per plant decreased markedly. Physiological characters like leaf chlorophyll and leaf nitrogen content increased but specific leaf weight (SLW), leaf β-carotene, stem and fruit nitrogen were decreased markedly with the reduction in the amount of light. Chlorophyll a/b ratio was lower in cucumber at 50% PAR level and yard long bean but the ratio remained almost unchanged in ash gourd and sponge gourd at all light levels. Leaf weight ratio (LWR) remained more or less similar up to 50% reduction of

PAR in cucumber and yard long bean, whereas it reduced in ash gourd and sponge gourd. Compared to 100% PAR the total dry matter (TDM) did not reduce in yard long bean, ash gourd and sponge gourd by reduction of light up to 75% PAR. But in cucumber the TDM did not reduce up to 50% PAR. The relative dry matter yield of cucumber, yard long bean, ash gourd and sponge gourd at 50% PAR were 0.90, 0.81, 0.75 and 0.76, respectively. Crop duration increased by different reduced PAR levels due to delayed flowering and longer fruit development period. Eventually at 100% PAR level the fruit yield was 11.28 t/ha in cucumber, 11.03 t/ha in yard long bean,21.03 t/ha in ash gourd and 24.90 t/ha in sponge gourd. Cucumber and yard long bean showed significant fruit yield reduction only at 25% PAR, level whereas significant fruit yield reduction were observed at 50% PAR in ash gourd and at 75% PAR in sponge gourd. The relative fruit yield at 75% and 50% PAR were 1.43 and 1.04 in cucumber, 1.08 and 0.84 in yard long bean, 0.83 and 0.57 in ash gourd and 0.75 and 0.18 in sponge gourd. However, considering relative TDM and relative fruit yield cucumber and yard long bean were found suitable for reduced light condition (50% PAR). But ash gourd and sponge gourd were more sensitive to any reduction of light compare to cucumber and yard long bean.

BIOGRAPHICAL SKETCH

The author was born in a noble family on February 27, 1968 in the district of Kushtia, Bangladesh. He is the only son of late Ahsan Ullah and Mrs. Rahima Bulbul.

He attended elementary schools in Kushtia. He passed Secondary School Certificate Examination from Shirajul Haque Muslim High School, Kushtia in 1984 and Higher Secondary Certificate Examination from Kushtia Govt. College in 1986. He obtained 1st division in both examinations. He secured B. Sc. Ag. (Hons.) degree from the Bangladesh Agricultural University, Mymensingh in 1990 (exam. held in 1994) and obtained 1st class securing 18th position.

He started his professional career on 30th January, 1995 as Lecturer; Department of Crop Botany at Patuakhali Agricultural College, Patuakhali. In December, 1998 he was transferred to Haji Mohammad Danesh Agricultural College, Dinajpur and has been working at the same post in that college till today.

The author enrolled at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) as M. S. student in the Department of Crop Botany in Autumn term, 1999. He maintained GPA of 4.00 out of 4.00 which is considered above First class.

He is happily married to former Miss. Narju Akter (Lima) in October, 2000.

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Autumn, 2001 **The Author**

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CHAPTER I

INTRODUCTION

Vegetables are one of the essential items of daily requirement. Improvement of daily dietary value depends largely on the vegetables consumption. The average consumption of vegetables in Bangladesh is only about 96 g per head per day (Anon., 1999) which is too low compare to the standard requirement of 200 g per head per day (Haque, 1995). So, vegetable production needs to be increased in Bangladesh.

Vegetables are not produced evenly throughout the year in Bangladesh. About 35% of the vegetables are produced in summer season and rest in the winter season (Rashid, 1999). Cloudy sky, low light intensity, excess rainfall, etc. are major problems for vegetable production in summer season. So, there is an ample scope and need to increase vegetable production in summer season. The development or identification of low light tolerant vegetables could be one of the achievable attempts to solve such problem.

Among the potential summer vegetables, major vine type vegetables are cucumber (*Cucumis sativa*), ash gourd (*Benincasa hispida),* sponge gourd (*Luffa cylindrica* and yard long bean (*Vigna unguiculata* ssp. *sesquipedalis)*. But the available recommended cultural practices of these crops (Cucumber, Ash gourd, Sponge gourd and Yard long bean) do not indicate their optimum growth and yield performance under partial or full shaded environment in homestead. However, reduced light or partial shade tolerance of these vegetables yet not being studied. So there is enough scope to study partial shade tolerance of these vine type vegetables. Secondly, summer vegetables are traditionally grown in homestead and its surrounding beneath the fruit and timber trees. There are about 19.4 million homestead in Bangladesh which comprises about 0.45 million hectares of land. Most of the vegetables produced and consumed in this country are coming from these homesteads (Anon., 1999). These areas are also increasing due to construction of new houses for the ever increasing population.

Shading reduces photosynthetically active radiation (PAR). Photosynthetically active radiation is the major factor regulating photosynthesis, dry matter production and yield of crops (Rao and Mittra, 1988). Plants encountering shading show decreased photosynthesis (Boardman, 1977) which ultimately induced yield reduction and possibly impairs fruit quality (Morgan *et al.,* 1985).

Adaptive responses of plant to low irradiance include an increase of leaf area ratio, leaf to stem mass ratio and stem length, decreased leaf thickness and root growth relative to shoot growth (Boardman, 1977; Cooper and Tainton, 1968; Corre, 1983; Tones, 1985). Increase LAR occurring with reduced SLW of plant grown under low irradiance has been associated with reduced leaf thickness (Corre, 1983). Leaf chlorophyll and β-carotene content also depend on light intensity. Shade reduces the total plant dry weight and N content in plant but increases in leaf N content (Fujita *et al.*, 1993).

Vegetables cultivation needs to be increased in homestead areas particularly during summer season. To serve this purpose, partial shade tolerant vegetables would perform better in respect of yield increase. However, under Bangladesh conditions research works, attempt to increase summer vegetables are limited. So, there is a tremendous need to screen summer vegetables under partial shaded environment and to identify the desirable crops and crop characters. It would be wised to conduct experiment under artificial shade condition for screening of different vegetables in term of their growth and yield.

In the view of proper utilization of homesteads, other shaded places and increasing production of summer vegetables, a study was undertaken on aforesaid four vine type vegetables under different light levels. The objectives of the study were:

1. To characterize the morphological and physiological behaviour of the selected vine type vegetables under different reduced light levels, and
2. To evaluate the yield and yield contributing characters of those vegetables under reduced light condition.

CHAPTER II

REVIEW OF LITERATURE

Cucumber, ash gourd, sponge gourd and yard long bean are important summer vegetables in Bangladesh. Low light during the growing season affect morpho-physiological characteristics, yield and yield parameters. Surprisingly very little work has been carried out in this aspect on aforesaid vegetables. However, in this section a brief review has been done on the results of related works in the recent past.

Competition for Light Resource

Shading reduces the photosynthetic capacity of plant. Among the basic growth resources viz. light is a major determinative factor for inevitable competition of the crops (vegetables species) grown in association with trees in homestead, resulting mark depletion in the productivity of under-story crops/vegetable. Among different limited resources light availability is one of the most important one. Performance of the under-story crops/vegetables, particularly, where an upper-story perennial forms a continuous over story because light is the only source that provide energy for photosynthesis which is the basis of vegetable or crop production. Unlike water and nutrients, light can not be captured and stored for later use in the way that other natural resources are managed (Miah, 1995). Limiting light (shade) is obviously the most important factor that causes poor performance of under-story crops. The key to the development of compatible tree-crop combination in agroforestry is greater light interception by under-story crops. In India, it is widely believed that shading by trees is responsible for poor yields of associated crops (Ong *et al.*, 1992).

The combination of tree and crop species in homestead offer much more scope for useful management of light interception and distribution than do mono-culture forests and agricultural crops (Miah, 1996). The potential benefits as a results of combining field crops with trees are so obvious from consideration of the waste of light resources experienced in orchard and tree crop orientations (Jackson, 1987) The severity of competition between under stored crop with trees in homestead ultimately crop yield is dependent upon the partitioning of resources, primarily of light and water between trees and crops (Howard *et al.,* 1995). Essentially the underlying processes involved in the partitioning of resources (e.g. light water and nutrients) are not well understood. A letter mechanistic understanding of resource capture and utilization in agroforestry system is required to facilitate the development of improved system in term of species combinations, planting arrangement and management (Howard *et al.,* 1995).

One of the major constraints of microclimate and growth of vegetable in homestead is solar radiation. Interaction among the trees and solar geometry produce the particular solar climate of a tree/crop system. These interaction and effects include interception of radiation by tree stands of various densities effect of canopy structure, effect of spacing, effect of latitude and time of year on solar paths shade from single croons and spectral quality of sun light under partial shade (Reifsnyder, 1987). Okigbo and Greenland (1976) and Oxigbo (1980) identified more efficient use of light resources by plants of different heights and canopy structures as one of the advantage to be gained by growing crops in mixed stands. The yield advantage of conventional intercropping has been explained in terms of improved capture or utilization of growth resources (Willey *et al.,* 1986). The resources capture by three/crop system (agroforestry) will probably be greater than in sole crops (Ong *et al.,* 1991).

Morphology

Shade has pronounced effect on morphological characters of many crops. It influences plant height, stem diameter (girth), internode length, number of primary branches per plant, leaf number per plant, leaf size thickness and leaf area etc. plant height increases gradually with the decreased light levels in okra (Ali, 1999), egg plant (Miah, 2001) mungbean (Islam, 1996) and chickpea (Murshed, 1996). But in red amaranth, plant height and stem girth decrease with reduction of photosynthetically active radiation (Ali, 1999 and Wadud, 1999). Shading produced taller tomato plant with longer internodes (Thomas and Teoh, 1983) and thinner stem (Bscetinulik *et al.*, 1994) plant grown in low light levels was found to be apically dominant than those grown in high light environment resulting taller plant under shade (Hillman *et al.,* 1984).

Increased stem elongation often accompanies moderate reductions in irradiance and is influenced by photosynthate availability and the capability of the plant to partition photosynthates into stem growth. Altered partitioning increases or maintains stem length at the expense of root growth and stem girth (Corre, 1983; Jones, 1985). Ultimately enhanced stem elongation is not observed when irrdiance is reduced to a level where all plant developmental processes are photosynthate-limited (Kephart *et al.,* 1992).

Variation in number of primary branches per plant due to shading is important because it contributes maximum towards the yield of grain legumes (Hossain *et al.*, 1996). Generally the number of primary branches per plant decreases gradually with the increase of shade levels but variation also found in different varieties of same vegetables. Okra grown under 75 percent PAR level produced more number of branches per plant (4.17) compare to 100 percent PAR level (3.75) (Wadud, 1990) and in tomato the maximum number of primary branches (3.27) was obtained at full sunlight and it gradually decreased with decreasing light level (Miah, 2001). The lower number of branches under shaded condition might be due to higher auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al.*, 1999).

Number of leaves per plant is influenced by different levels of shading and different vegetables response differently. Leaf number usually decreases under shading condition in most of the crops such as red amaranth, indian spinach and mungbean (Ali, 1999; Wadud, 1990; Islam, 1995). But in tomato and okra highest number of leaves produce at 75 percent PAR (Miah, 2001) and there is no variation in leaves number of kangkong from full sunlight (310.82) to 50% PAR (290.07). The lower number of leaves per plant may be due to lower production of photosynthates under low light condition for a longer period.

Plants grown at high light intensity have a different leaf morphology from those grown at low light intensities leaf size (length X breadth) increases under shaded condition in different vegetables such as cabbage, carrot, radish and tomato (Miah, 2001). This may be attributed due to the stimulation of cellular expansion and cell division under shade condition (Schoch, 1972). But in red amaranth and indian spinach leaf size progressively decreases with decreased PAR level (Ali, 1999); Yoshida and Parao, (1976) reported vegetables grown under shade condition had smaller leaves and shading did not have significant influence on leaf size of kangkong (Wadud, 1999). Shading reduced leaves number, leaf thickness and leaf area (Crookston *et al.,* 1995).

Higher light intensity causes a stronger development of the palisade and spongy mesophyll region resulting in thicker leaves (Bjorkman *et al.,* 1972). The shading decreases the thickness of leaf mesophyll (Nygren and Killomati, 1983) and this occur due to formation of thinner palisade layer (Rom, 1990). Variation in leaf thickness occurring with adaptation to solar radiation are often associated with differing cell number per unit of leaf thickness (Boardman, 1977). Leaf area is made up of the total green lamina area of emerged leaves (Keating and Carberry, 1993).

Leaf area in mungbean might be increased due to heavy shading (Kubuta and Hamid, 1992) and leaf area increases also in tomato and cucumber (El Abd, 1994); shading increases leaf area by increasing leaf length (Tsuno and Yamoguch, 1989).

Leaf blades on Tall Fescue plant at low irradiance were 54% longer and had 56% more leaf area but were 12% thinner and had 8% lower specific leaf weight than those grown at high irradiance. Shade plants allocate more dry weight to production of leaf area and a blade grows at low irradiance has 25% more air space (Allard *et al.,* 1991a). Morphometric comparison indicates shade plant bears fewer leaves, has less leaf overlap, increases leaf area ratio and longer petiole than full sun plant. Leaf elongation rates are low and the duration between the emergence of successive leaves is longer in shade plant (Niklas *et al.,* 1989). Growth in width and thickness is decreased at low irradiance in Tall Fescue plant resulting in only a 12% increase in leaf area production and 5% less total growth associated with water deposition than at high irradiance (Schnyder *et al.*, 1989). Total leaf area in grasses increased significantly whereas legume leaf area increases slightly under shade conditions (Morita *et al.,* 1994). Higher LAR with concurrent low SLW under low irradiance has been associated with development of relatively large and thinner leaves (Corre, 1983 and Rolson *et al.,* 1988).

There is a functional relationship between crop growth and leaf area (Wilson, 1981). Shading reduces the volume of photosynthetic cell per leaf or per unit leaf area (Wilson and Cooper, 1969). Shading caused an increase in 98% in mesophyll resistance to diffusion of CO_2. Stomatal resistance to CO_2 diffusion increased by

48% (Cookston *et al.,* 1975; Woledge, 1977). This resistance impair biological reaction of leaf and under heavy shading effective leaf area is reduced (Imai *et al.,* 1993).

Under shade condition leaf senescence is delayed (Sheldrake and Sayena, 1979) which might prolong the reproductive phase i.e. life ripen of shade grown plants and root growth reduced (Andersen *et al.,* 1993). Weight of leave remains infected and Stomatal density decreases at both side of leaves grown at low irradiance (Marler *et al.,* 1994).

Chlorophyll and β-carotene

Shade affects the chlorophyll and β-carotene content in leaves. Partial shading increases the quantity of chlorophyll in leaf (George and Nair, 1990; Islam *et al.,* 1993 and Marler *et al.,* 1994). The lower light intensity from shading caused an increase in synthesis and accumulation of chlorophyll to harvest more light (Chen *et al.,* 1994). Chlorophyll a, chlorophyll b, carotenoid and total pigment contents in leaves increased with increased shading (Andersen *et al.,* 1985 and El-Gzawy *et al.,* 1993). All suny leaves of annual crops (cucumber, egg plant, sunflower, tomato, bush bean, cabbage and muskmelon) contained considerably greater amount of β-carotene than shade leaves. Alpha carotene is not present in the sun leaves of these annual crops but is present in large amounts is all shade leaves (Adams and Adams, 1992). At the commencement of shading, chlorophyll and caroteniod contents of shaded upper leaves were 53% and 25% higher than those of similar unshaded leaves in cotton. Differences were smaller in older leaves, lower in the canopy where light penetration was reduced (Teles and Silveira, 1985) under simulated shade conditions. The efficiency of photosynthesis was maintained by absorption of more light by the accessory pigment and by increasing amount of chlorophyll b (Hilton, 1983). Boardman, 1977 reported that leaves grown under low photosynthetically active radiation (PAR) had more chlorophyll per unit dry weight but that chlorophyll content per unit leaf are was often lower than in leaves grown at higher PAR. The maximum photosynthetic rate and light intensity for photosynthetic saturation were decreased in shading. Both phenomena seemed to be associated with the increase in specific leaf area (SLA) and the decrease in the amount of chlorophyll content per unit of leaf area (Nygren ind Kellomaki, 1983). But Allard *et al.* (1991) found that chlorophyll content per unit leaf area was not influenced by shading and chlorophyll content per unit dry matter (DM) was higher for shade grown leaves in Tall Fescus probably because the leaf tissue was less dense due to fewer mesophyll cell and more water space.

Total chlorophyll content in shade leaves was about three times greater than in exposed leaves in kiwi fruit. Chlorophyll a and chlorophyll b were usually higher in shade leaves than in full sun leaves. Although chlorophyll a and b both increased in shade leaves, leaves expose to sun showed a higher a/b ratio. The relative increase in chlorophyll b may enhance the ability of shaded leaves to capture and utilize the light transmitted by exposed leaves (Chartzoulakis *et al.,* 1993). Chlorophyll b and caroteniods protect the plant cell against photo-chemical reaction induced by the illumination of chlorophyll (Davies *et al.,* 1964). N-content was higher in leaf grown at low irradiance in cucumber and *Phaseolus vulgaris* (Evans, 1989). Shade reduced total plant weight and N content in all legume (Fujita *et al.,* 1993 and Hayati, 1995). Increase in shoot N concentration. is an adoptive mechanism of shade plants (Nyarko *et al.*, 1993). Water use efficiency is greater for sun plant than that of shade plant (Valenzuala, 1991).

Yield and Yield Parameters

Reduced light was found to affect yield and yield attributes of all crops. Generally yield of vegetables is less affected under shade than grain crops. In tomato, number of fruits per cluster, fruit diameter and individual fruit weight decreased with reduction of PAR levels and other attributes such as number of cluster per plant, number of fruits per plant and yield increase up to 25 percent reduction of PAR. Further reduction of PAR caused decrease of yield parameters and yield (Aidy, 1984 and Miah, 2001). Similar trend of yield is found in okra (Ali, 1992). Nyarko *et al.*(1993), observed that the translocation is enhanced under slightly reduced light but further reduction of light affects translocation due to limitation in energy supply.

The fruit yield of bottle gourd is higher at full sun light (57.52 t/ha) compare to 75 percent (54.49 t/ha) and 50 percent PAR (34.45 t/ha). All yield parameters viz. Number of fruits per plant, fruit length, diameter, individual fruit weight are also higheer at full sun light. The yield of sweet potato did not vary much up to 50%

reduced PAR and higher yield is obtained at 25% reduced PAR but under severe shade condition yield drastically reduced. The yield performance of sweet potato at 25% reduced light condition is contributed by the better performance of tuber number and tuber weight per plant those may be controlled by their genetic attributes (Miah, 2000). He also reported that olkachu, mukhi kachu, tarmaric and zinger show similar trend of yield like sweet potato. The yield of these root crops drastically reduced under severe shade condition (25% PAR) because of mobilization of reserve assimilates to storage is limited (Ali, 1998 and Laosawan *et al.,* 1992) in mungbean.

The biomass allocation to the cucumber fruits increases with increasing irradiance which increases the number of fruits growing at the same time on the plant. The growth rate of individual fruit increased with increasing irradiance resulting in a shorter growing period from anthesis until harvest maturity and dry matter percent increased in both fruit and the vegetative parts at higher irradiance (Marcelis, 1993). The number of days from sowing to flower appearance increase as the shading level increased whereas the number of flowers /plant decreased under all shading rate compare with full sunlight (Menzel and Simpson 1989; and El-Gizawy *et al.,* 1993). Flower induction tend to occur later in shade plant (Buge *et al.,* 1987).

In egg plant, number of fruit per plant, fruit length and yield are highest at full sunlight but fruit diameter and individual fruit weight are higher at 75 percent PAR. With the decrease of irradiance yield decreases gradually (Miah, 2001). Similar trend of yield is also found in leafy vegetable indian spinach and red amaranth (Wadud, 1999). Cabbage gave the highest yield under partial shading (30 to 40% PAR). Head length, breadth, fresh weight dry weight are also higher at partial shade condition (Wolff and Cottman, 1990). Park *et al.* (1982) found that shading (30-47% PAR) increases head yield of cabbage and chinese cabbage by 23% and 21% respectively compare to full sunlight. Twenty four percent shading level increases cabbage yield by 14.59% compare to full sunlight (Miah, 1999).

Amaranth is grown successfully under drumstick tree although 10-15 percent yield was reduced compare to open field but under guava tree yield is very poor probably due poor PAR availability due to bushy branching habit of guava trees (Ali, 1999). But Wainwright (1995) reported that biomass production of amaranth was not reduced relative to the controls at light level up to 58% of total PAR. Leafy vegetable kangkong produced higher yield under 75% PAR level (Wadud, 1999).

The yield of pineapple would be maximum at a mean season PAR of 611 m mole $m^{-2}S^{-1}$ or 55% of open field condition and such a light condition occurs in jackfruit orchards with an estimated crown cover of 9803 lm $m^{-2}ha^{-1}$ (Hossain, 1999).

Yield of rice is lower under partial shade condition (Nayak and Murty, 1980). This is mostly due to impair dry matter production, panicle number and grains per panicle. Fifty percent shading during ear formation and milking stage of rice decreased yield by 48% and 18% respectively (Park and Kwon, 1975). Pre-flowering shade (50% of normal light) results in reduced tiller number, spikelet per panicle whereas post-flowering shade reduced filled spikelets fraction and grain weight in rice (Chaturvedi and Ingram, 1989).

Yield of legumes are attributes by number of pod per plant, number of seeds per pod and seed size. These attributes are severely affected by degree of shading. The number of pods per plant is the most important trait that contribute to higher yield (Hassan *et al.,* 1996). Pod formation in a plant may be influence greatly by light intensity and duration of shading (Abiday and Lantican, 1982). Jian and Egli (1993) observed that shade induced environment changed flowering, delayed flowering and reduced the number of pod per plant in soybean. Reduction of pods per plant was the resultant of both flower and pod abscission under the shade. Shade also affects the number of nodes on the main stem as well as flower nodes which ultimately reduced the number of pods per plant. Number of seeds per pod and seed size of legumes is further affected by shade. Consequently seed yield is always higher in full sunlight. The yield of mungbean reduced by 70% under shade (40% PAR) condition (Lantican and Cafedral, 1977). The higher yield of mungbean in the full sun light associated with higher rate of photosynthesis and partitioning of higher amount of photosynthates towards its grain (Liyanage and McMillian, 1981a; 1981b; Laosawan *et al.,* 1992). Under shade condition, plant expense more energy to structural development compare to the plant grown under full sunlight (Hamid *et al.,* 1990).

CHAPTER III

MATERIALS AND METHODS

The study was conducted at the research plots of the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University during April to November, 2000 under upland condition. This study was a part of the project tied progromme of the Department of Agroforestry and Environment. The experimental site is located at 24° 09' North Latitude and 90° 26' East Longitude and situated at 8.20 m above the mean sea level (Anon., 1989). Four separate experiments were included in the present study. The materials and methods of these experiments were almost similar.

Climate and Soil

The site of the study was characterized by a tropical climate (Appendix 5). The hot and dry weather prevails during March to May with the mean maximum of 34.4°C. The cool and dry weather prevails during November to January and characterized by the mean temperature 11.9°C. Temperature during the monsoon (June to September) is moderately hot but highly humid. Mean annual rainfall of the site was 2070 mm. About 1760 mm of this rainfall i.e. 85% occurred during the months of May to September. Remaining 14.9% of rainfall occurred during October to March.

The soil of the experimental field was originally shallow red brown terrace of Madhupur clay under Salna Series. But the texture has been changed to loamy by putting recent alluvial soil i.e., the surface soil is artificial alluvial loam with red Madhupur clay underneath.

Plant materials used

Four summer vegetable crops used in this study were as follows:

Crops	Variety	Source of seed
Cucumber	Baromashi	BADC
Ash gourd	BU ash gourd-1	BSMRAU
Sponge gourd	Local (white)	Local market
Yard long bean	Kagonutki	BADC

Treatments

The following four treatments i.e. four PAR levels were used in this study.

T_1- 100% Photosynthetically Active Radiation (PAR)/ Full sunlight (1150 μ mole $m^{-2}S^{-1}$ measured at 12 0' clock)

T_2- 75% PAR i.e. 863 μ mole $m^{-2}S^{-1}$

T_3- 50% PAR i.e. 575 μ mole $m^{-2}S^{-1}$ and

T_4- 25% PAR i.e. 432 μ mole $m^{-2}S^{-1}$.

The full sunlight was considered as of 100% PAR. So that, the crops received 100% of natural solar radiation. Light (PAR) was recorded by using sunfleck ceptometer (Model 800-755-2751). The remaining treatments of reduced sunlight were consisted of 75%, 50% and 25% PAR.

Experimental Design and Layout

The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Four summer vegetables were grown separately following the same design. The individual (unit) plot size for each vegetables was 3 m X 2 m. Adjacent plots and neighbouring blocks were separated by 2.5 m and 1.0m.

Raising of Seeding

Polybags of 15 cm X 10 cm size were filled with mixture of sandy loam soil and well decomposed cowdung. There were two holes at the lower side of the poly bag for drainage of excessive water. Seeds were sown in polybags on 18 April 2000. Two seeds were sown in each bag. After sowing seeds, the polybags were kept in the shade to complete the germination. Then the seedlings were transferred along with the polybag to a sunny place. After 7 days of emergence only one seedling was allowed to grow in each bag. Intensive care was taken to protect the seedlings from the attack of insects and water was applied to the bags by water can regularly.

Land Preparation

The land used for the experiments was first opened one week before laying out the experimental plots. The land was well prepared with the tractor followed by harrowing and laddering up to a good tilth. All weeds and stubbles were removed.

Pit of 30 cm X 30 cm sizes were dug according to the recommended planting (1.5 m) distance after lay out of the plot. The pits were filled with manure so that the upper soil goes to the bottom of the pit and the bottom soil to the upper surface.

Manure and fertilizer application

For cucumber, ash gourd and sponge gourd manures and fertilizer were applied at the following rates :

Manures/fertilizer	Dose/unit plot	Dose/ha
Cowdung	6 kg	10 ton
TSP	75 g	125 kg
Urea	90 g	150 kg
MP	60 g	100 kg

According to Rashid, 1999.

For yard long bean, manures and fertilizer were applied at the following rates:

Manures/fertilizer	Dose/unit plot	Dose/ha
Cowdung	6 kg	10 ton
TSP	90 g	150 kg
Urea	80 g	50 kg
MP	90 g	150 kg

According to Rashid, 1999.

At the time of land preparation, half of the cowdung was applied. Rest of the cowdung i.e.1.5 kg/pit and the whole quantity of TSP @ 37.5 or 45 g/pit (according to crops) were applied 15 days prior to transplanting in the pit. The urea and muriate of potash were applied in two instalments consisting of ½ at each instalment. The first instalment was applied 10 days after transplanting the seedlings. The second instalment was applied at 15 days after the first instalment. But in case of sponge gourd second instalment was applied 30 days after the first instalment.

Transplanting and Crop Management

Seedlings of all four vegetables were transplanted in the experimental field on 11 May 2000. Only healthy seedling was transplanted in each pit. Before transplanting of seedlings, the polybags were removed from each seedling to facilitate out growth of root from basal media so that they can establish in the field. At the time of removing polybags, care was taken to prevent the damage of the bagged soil. Transplanting was done in the afternoon and light watering was done around each seedling for their better establishment.

The experimental plots were kept weed free by weeding frequently. The plots were irrigated whenever needed by using hose pipe to supply sufficient soil moisture for the vegetables.

Seedlings of cucumber and ash gourd were infested by red pumpkin beetle. To control the pest, Diazinon M-60 was sprayed @ 1 ml/l water at 5 days interval up to 25 days after transplanting. Simboush was sprayed @ 2 ml/l water on yard long bean to control bean fly.

Establishment of Shading Treatments

When crop establishment was completed, mosquito nets of different sieve sizes were hanged with the help of bamboo sticks at a height of 2.3 meters to create low light treatments. Low light treatments consisted of 75% photosynthetically active radiation (PAR), 50% PAR and 25% PAR. No net was used on the control (T_1) plots and the treatment consisted of full sunlight or 100% PAR.

Harvesting

Yard long bean was harvested in several pickings when the fruit reached at edible maturity. The harvesting was started at 37 DAT and ended at 127 DAT. Ash gourd was harvested at 40 days after transplanting when fruit reached at marketable size and continued upto 121 (DAT). Cucumber harvesting started at 47 days after transplanting and ended at 124 DATP. Sponge gourd was first harvested at 72 days after transplanting and continued up to 193 DATP. The marketable size of fruit was determined visually and by pressing the fruit with nail.

Data Collection

Data on following parameters were collected from each experiment.

a) Morphological parameters

Data on individual leaf area, leaf number/plant, internode length, mainstem length, main stem diameter, days to first flower crop duration, leaf dry weight and stem dry weight were recorded. Leaf area was measured by using green leaf area meter (Model GA-5): Internode length was determined by measuring distance between 5th and 6th nodes. Crop duration was estimated by counting days from transplanting to last crop harvest 10 leaves were selected from 5th and 6th nodes of randomly selected plants. Dry weight of leaves has taken by drying 10 leaves in oven at 65°C for 72 hours and then the average leaf dry weight was calculated. The leaf dry weights per plant were calculated by multiplying the leaf numbers per plant and average leaf dry weight. Senescent stem and its branches were collected and dried as above for calculation of stem dry weight.

b) Yield and yield contributing parameters

Data on yield and yield contributing characters/parameters like fruit number per plant fruit length, fruit diameter individual fruit weight, fruit yield and fruit dry weight per plant were also recorded. Average fruit length and individual fruit weight were measured from 10 randomly selected fruits. Digital slide callipers was used to measure fruit diameter. It was done by measuring middle portion of the fruit. Fruits/plant were counted and weight of each fruit was taken to calculate fruit weight per plant. Finally yield per hectare was computed by multiplying total number of plants and average fruits weight per plant. Fruit dry weight was taken using the same temperature and time for leaf dry weight after making slice of 10 randomly selected fruits. Finally fruit dry weight per plant were computed.

With the help of above recorded data specific leaf weight (SLW) leaf weight ratio (LWR) and relative yield were calculated using followign formula : (Schoch, 1972).

SLW = Leaf dry weight (mg) ÷ area of leaf (cm^2)

LWR = Leaf weight ÷ above ground dry weight

$$\text{Relative yield} = \frac{\text{Dry yield of treated plant}}{\text{Dry yield of control plant}}$$

c) Physiological analysis

Chlorophyll: Chlorophyll content in leaf was determined on fresh weight basis extracting with 80% acetone and used double beam spectrophotometer according to Witham *et al.* (1986).

Amount of chlorophyll were calculated using following equations/formula

$$\text{Chlorophyll a (mg/g)} = [12.7(OD_{663})-2.69\ (OD_{645})]\ \frac{V}{1000\ W}$$

$$\text{Chlorophyll b (mg/g)} = [22.9(OD_{645})-4.68\ (OD_{663})]\ \frac{V}{1000\ W}$$

$$\text{Chlorophyll a+b (mg/g)} = [20.2(OD_{645})-8.02\ (OD_{663})]\ \frac{V}{1000\ W}$$

where OD = Optical density regarding of the chlorophyll extract at the specific indicated weave length.

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissue extracted.

Finally chlorophyll content was converted to dry weight basis using leaf dry matter percentage.

β- Carotene: β-carotene content was estimated from the same extract used for chlorophyll estimation. This method was developed by Shiraishi (1972). The amount of β-carotene was calculated using the following formula :

$$\beta\text{-carotene (mg/g)} = 3.984\ (OD_{451})V/1000W$$

V = Total volume of the petroleum ethere β-carotene extract (ml) and

W = Fresh weight of the sample taken (g).

Nitrogen content: Plant parts (stem, leaf and fruit) were collected from respective plant. Then the samples were oven dried at 70°C for 72 hours. The dried samples were grind and analyzed in the laboratory, BSMRAU, Gazipur-1703, Bangladesh to the N content of the plant parts by modified kjeldahl method (Black, 1965). The amount of N was measure using the following formula.

$$\%\ \text{of N} = 14.007 \times 0.02\ (N)\ H_2SO_4 \times f\,(T-B) \times \frac{100}{10} \times \frac{100}{Y}$$

where, T = Amount of 0.02 (N) H_2SO_4 required in titration of the plant extract (ml)

B = Amount of 0.02 (N) H_2SO_4 required in blank titration (ml)

f = 1.07 (correction factor)

Y= Weight of the sample in milligram.

Statistical Analysis

The collected data on morphology, physiology and yield contributing characters of the four vegetables were statistically analyzed with the help of computer by using MSTAT programme. The analysis of variance for each of the studied character was done by F (variance ratio) test for Randomized Complete Block Design. The treatments means were compared by least Significant Difference (LSD) Test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the four experiments on various changes in morphology, phenology, dry matter accumulation, pigment content, nitrogen content, yield and yield components. have been discussed and presented separately.

Morpho-physiological and yield performance of cucumber under variable light levels

Morphology

In cucumber, the main stem length was increased significantly at all levels of reduced PAR compared to full sunlight (Table 1). The highest main stem length was observed at 50% PAR level (6.30 m). Higher length of main stem was also observed under reduced sun light in bottle gourd (Miah, 2000) and in chickpea (Murshed 1996). Cucumber plant exhibited the longest internode at 25% PAR level (10.39 cm) and the shortest length was obtained under full sunlight (8.11 cm). Under reduced sun light, the concomitant increase in main stem length and internode length clearly explained the contribution of internode length to main stem length. This was probably due to higher apical dominance under shade condition (Hillman, 1984). Diameter of main stem was also significantly affected by reduced PAR levels. Highest diameter of main stem was recorded from 75% (3.09 cm) as well as 100% PAR level (3.04 cm). The lowest diameter was obtained from 25% PAR (2.08 cm).

Similar reduction of stem diameter with decreasing light was also reported by Tuzel and Gul (1994). Corre (1983) reported that stem length increased at the expense of root growth and stem girth.

The leaf numbers per plant was significantly reduced by shade treatments. The highest number of leaves per plant was obtained from full sunlight (309), which was statistically similar with 75% (305.8) and 50% (238.3) PAR levels. The lowest number of leaf was produced under 25% PAR levels (214.0) and no significant variation was observed between 25% and 50% PAR. Significant increase in individual leaf area was observed when the PAR level was decreased up from 100% (222.2 cm^2) to 25% (529.1 cm^2) PAR levels. Under partial shade condition stimulation of cellular expansion and cell division in leaf could be one of the possible factors that contribute to the individual leaf area increase (Schoch, 1972). Similar to leaf number, the specific leaf weight (SLW) was also significantly reduced by reducing PAR levels. Among the four PAR levels, the highest SLW was recorded from full sunlight (3.08 mg/cm^2) which was statistically identical to that of 75% PAR level (2.83 mg/cm^2). The significantly lowest SLW was obtained from 25% PAR level (2.15 mg/cm^2). Decrease SLW at low light levels apparently indicates that the low PAR levels resulted in reduction in leaf thickness. Corre (1983) reported that reduced SLW of plant grown under low irradiance has been associated with reduced leaf thickness i.e. reduced palisade layers.

Table 1: Stem and leaf characteristics of cucumber in the different light conditions

Light levels (% PAR)	Main stem length (m)	Internode length (cm)	Main stem diameter (cm)	Leaves/ plant	Leaf area (cm^2/leaf)	SLW (mg/cm^2)
100	4.59	8.11	3.04	309.00	222.2	3.08
75	5.56	8.77	3.09	305.80	266.0	2.83
50	6.30	9.85	2.56	238.30	398.1	2.42
25	5.80	10.39	2.08	214.00	529.1	2.15
LSD(0.05)	0.92	1.45	0.13	72.87	68.41	042
CV (%)	8.17	7.81	6.50	13.80	9.68	8.15

Crop phenology

Crop duration increased significantly with reducing light condition (Figure 1). The highest crop duration was recorded under 25% PAR level (124.0 days) where as the shortest crop duration was observed under full sun light (89.33 days). There was no significant variation between 75% (99.17 days) and 50% (111.50 days) PAR levels in respect of crop duration.

The shortest time to flower was observed under full sunlight (27days). Whereas the longest time to flower was recorded under 25% PAR level (33days). So, shading somewhat delayed time to flowering. Similar finding was reported by Buge *et al.* (1987). Therefore, the reproductive period (first flower to maturity) was longer under reduced light levels compare to full sunlight.

Remarkable variation in fruit development period was observed in different PAR levels (Figure 2). Fruit development period was the shortest under full sunlight (5.33 days) and the longest was under 25% PAR level (6.94 days). The longer duration of individual fruit under reduced sunlight, contributed to the longer crop duration by enhancing the post- anthesis growth phase. This is clearly visible at 25% PAR level compared to 100% PAR level.

Dry matter accumulation and partitioning

Different PAR levels exerted significant effect on the dry matter accumulation in leaf, stem and fruit (Figure 3). At 100% PAR level, the maximum stem dry matter (129.3 g/plant) was harvested. The stem dry matter although reduced with decreasing PAR level, but the reduction was significant only at 25% PAR level

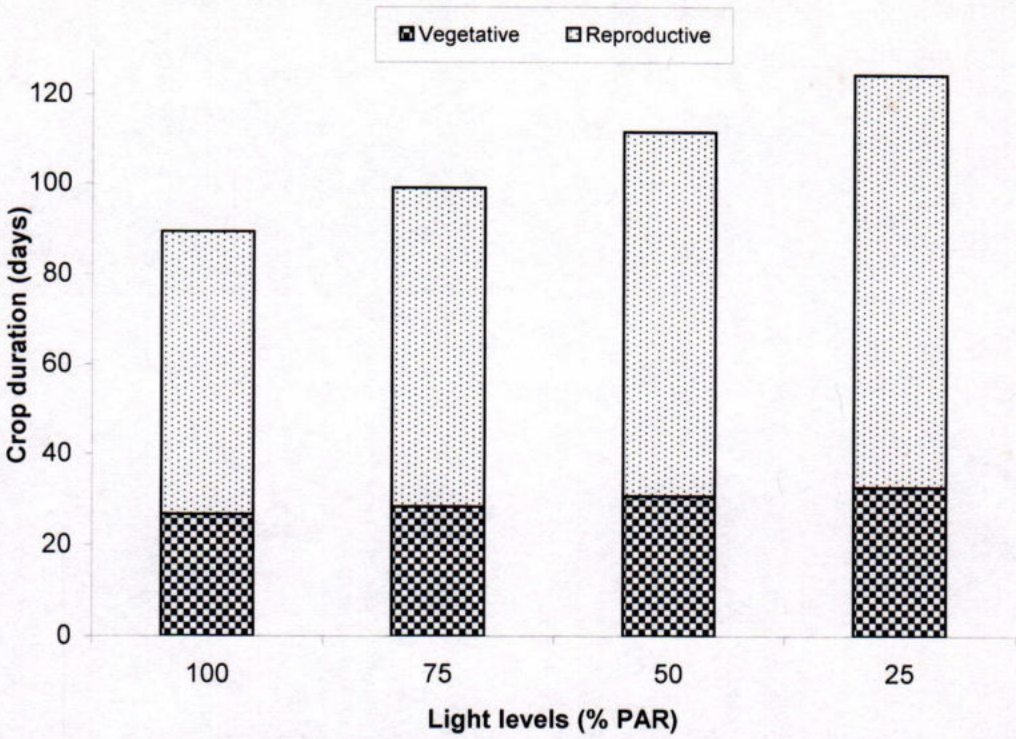

Fig.1: Duration of vegetative and reproductive phases of cucumber as influenced by different light levels.

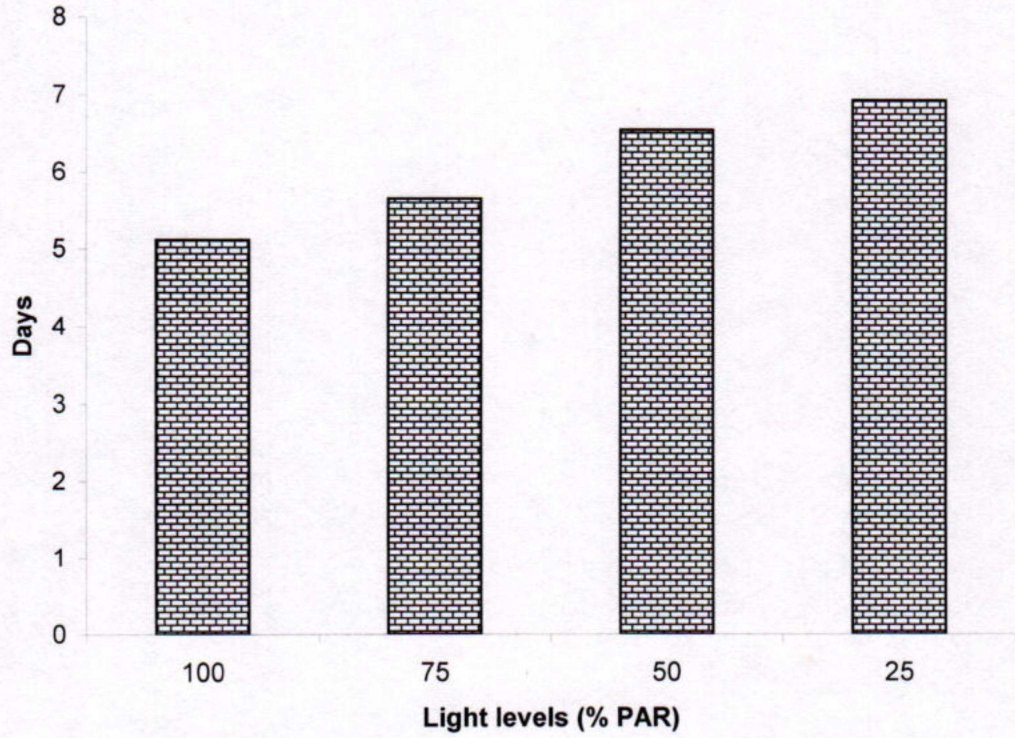

Fig.2: Fruit development period (anthesis to harvest maturity) of cucumber as influenced by different light levels.

compared to full sunlight. The lowest stem dry matter was produced under 25% PAR level (91.62 g/plant). Reduction of leaf dry matter with decreasing PAR levels was almost similar to that of stem dry matter. The lowest leaf dry matter was produced by 25% PAR level (181.6 g/plant) while the highest leaf dry matter of 227.3 g/plant was produced under full sunlight. However, fruit dry matter under 75% PAR (177.7 g/plant) was found to be higher compared to fruit dry matter under 100% PAR (133.8 g/plant). Under 75% PAR level, stem and leaf dry matter decreased compared to that of full sunlight whereas fruit dry matter increased. The dry matter partitioned to the fruit under 75% PAR level was higher compare to other treatments. Total dry matter (TDM) production in cucumber plant was significantly affected by varying PAR levels (Table 2). The highest amount of TDM (515.3 g/plant) was obtained under 75% PAR level which was statistically similar to that of full sun light (490.4 g/plant). PAR levels below 75% PAR level produced relatively small amount of TDM. The TDM recorded under at 25% PAR level (318.4 g/plant) was the lowest. The result also suggested that mild-shading stress stimulated the total dry matter accumulation in cucumber but with increasing the shading stress total dry matter production decreases. Reduced PAR levels had significant influence on leaf weight ratio (Figure 4). The LWR was lower at 100%, 75% and 50% PAR levels, which then increased at 25% PAR level (0.57). There is no significant variation among 75% (0.42), full sunlight (0.46) and 50% (0.47) PAR levels. Reduction of PAR levels from 100% to 50% did not affect the percentage distribution of total dry matter to leaf. But at 25% PAR level major dry matter was retained in leaf in expense of the total dry matter. The higher relative total dry matter under 75% PAR level (1.05) compared to other lower and higher PAR levels (0.90 to 0.65) (Figure 5) indicates that cucumber plants have got some advantage at 75% PAR level in term of fruit yield.

Under 25% light, cucumber plant showed considerable reduction in total dry matter compared to full sunlight which in turn was attributed to poor leaf, stem and fruit dry weight. But high LWR at 25% light suggests that leaf dry weight was less adversely affected relative to other components of TDM. Keeping the leaf minimal affected, cucumber plants expressed their tendency to minimize the low light stress by involving more foliar tissue in light harvesting. However, inspite of such changes to cope with low light stress, cucumber plant was found to be unsuccessful as indicated by poor total dry matter production at 25% PAR level. But experiments with large number of genotypes may be suggested to make clear conclusion.

Leaf pigment

The pigment contents viz. chlorophyll a, chlorophyll b, chlorophyll a/b ratio and β- carotene differed under different PAR levels (Table 2). The lowest chlorophyll a content was recorded under 100% light (8.72 mg/g) which was statistically different from other treatments. The chlorophyll a content gradually increased with the reduction of PAR level. The highest quantity of chlorophyll a in leaf was obtained from 25% light (15.23 mg/g). Chlorophyll b also showed similar increasing pattern with the decreasing PAR levels. Significantly the highest amount of chlorophyll b was observed under 25% PAR level (9.08 mg/g) while the lowest chlorophyll b content was under full sunlight (3.60 mg/g).

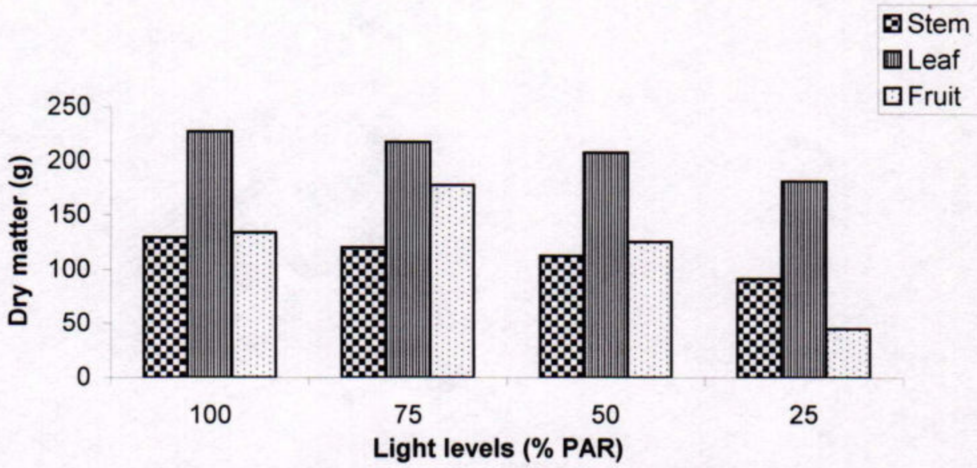

Fig. 3: Distribution of dry matter in different above round parts of cucumber in different light levels

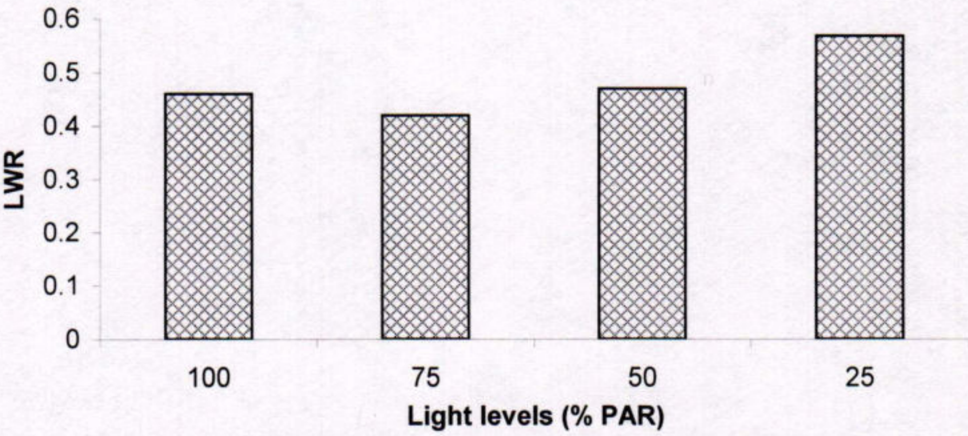

Fig. 4: Leaf weight ratio of cucumber as influenced by different light levels.

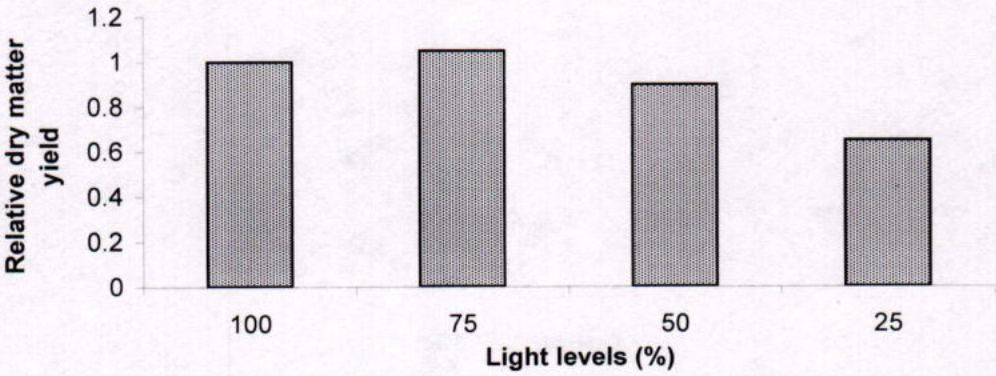

Fig.5: Relative dry matter yield of cucumber as influenced by different reduced light levels

The ratio of chlorophyll a/b gradually decreased with the decrease in PAR levels. The ratio of chlorophyll a/b was higher in full sun light (2.41) as well as in 75% light (2.28). Chlorophyll a/b ratio was significantly lower under 50% PAR level. Which further lowered to 1.68 under 25% PAR levels. Lower ratio of chlorophyll a/b under reduced sunlight of 50% or below compared to either 75% or 100% sunlight suggests the less extent of reduction of chlorophyll b than that of chlorophyll a. Under shading condition the efficiency of the photosynthesis was maintained through absorption of more light by the accessory pigments and by increasing chlorophyll b (Helton, 1983).

Total chlorophyll (a+b) content also maintained by a pattern of increasing value similar to chlorophyll a under reduced light condition. The highest amount of total chlorophyll was produced under 25% PAR level (24.06 mg/g). Then it gradually decreased with the increase in PAR level up to full sunlight. The lowest amount of total chlorophyll was observed under full sunlight. The lower light intensity due to shading caused an increase in synthesis and accumulation of chlorophyll (Chen *et. al.*, 1994). A linear relationship between PAR levels and leaf chlorophyll content of cucumber was found to be highly significant (R^2= 0.749**) (Figure 6). The variation in the leaf chlorophyll content of cucumber with the variation of light is well explained by the relationship.

Plant grown under reduced light condition had significantly lowered the amount of β-carotene in the leaves. The highest amount of β-carotene in leaf was recorded under full sunlight (4.21 mg/g) followed by 75% (3.28 mg/g), 50% (3.33 mg/g) and 25% (2.36 mg/g) PAR levels. But there was no statistical difference

Table 2: Chlorophyll and β-carotene content (mg/g) in the leaf of cucumber at different light levels

Light levels (% PAR)	Chlorophyll a	Chlorophyll b	Chlorophyll a/b	β-carotene
100	8.72	3.60	2.41	4.21
75	11.03	4.72	2.28	3.28
50	12.17	5.82	2.08	3.33
25	15.23	9.08	1.68	2.36
LSD (0.05)	2.03	0.73	0.14	0.68
CV (%)	7.97	6.30	3.04	10.38

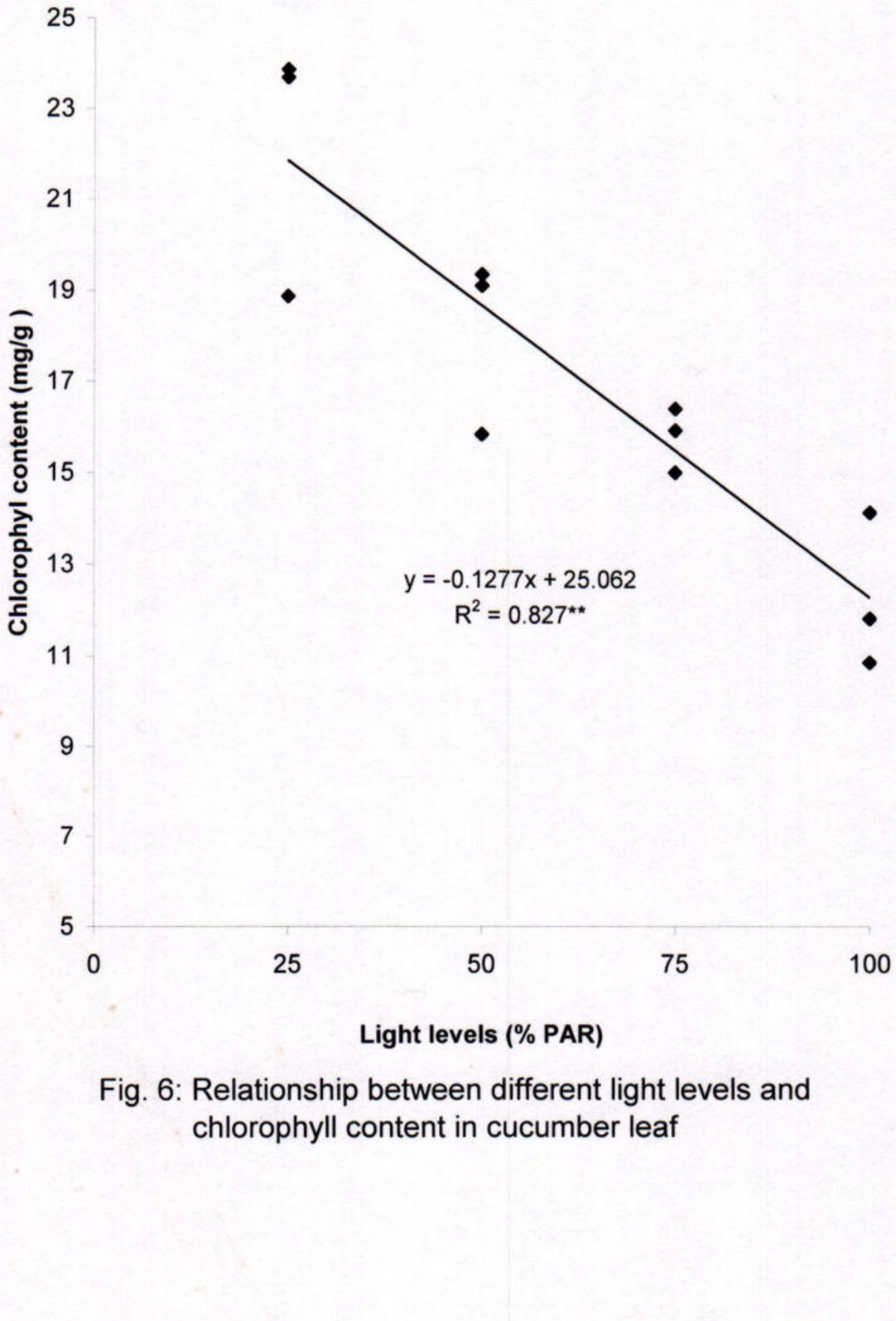

Fig. 6: Relationship between different light levels and chlorophyll content in cucumber leaf

between 75% and 50% PAR levels in respect of β-carotene content. The result was in agreement with that of Adams and Adams (1992) as they also found a reduction of β-carotene under shaded condition in cucumber although α-carotene content was increased.

Nitrogen content

Stem nitrogen varied from 2.17 g to 1.98 g per 100 g of dry tissue under variable light treatments (Table 3). But this variation was found to be non-significant. The amount of leaf nitrogen was the lowest under full sunlight (2.88 g/100 g) and it then increased slightly under 75% PAR level (3.04 g/100 g) but the difference was not significant. The highest amount of leaf nitrogen was recorded from 25% PAR treatment (3.53 g/100 g) which was statistically similar to that of 50% PAR level (3.30 g/100 g) but significantly higher compared to leaf nitrogen content under any other higher levels of light in this experiment.

There existed a linear relationship between leaf chlorophyll and leaf nitrogen content estimated as $y = 0.0557x + 2.1906$ (R^2=0.6356*) where the R^2 value is significant (Figure 7). The linear relationship indicates that leaf nitrogen content increases with the increase of leaf chlorophyll content. Under reduced light conditions the cucumber leaves were appeared to be deep green in colour compared to full sunlight. The increased chlorophyll content under reduced sunlight induced deep green colour to the leaf which, in turn, resulted in higher foliar nitrogen content.

Table 3: Nitrogen content in the above ground parts of cucumber at different light levels

Light levels (% PAR)	Nitrogen content (g/100g)		
	Stem	Leaf	Fruit
100	2.15	2.88	3.19
75	2.17	3.04	3.06
50	2.02	3.30	2.91
25	1.98	3.53	2.77
LSD (0.05)	Ns	0.31	0.28
CV (%)	5.03	5.27	4.51

Fruit nitrogen content also adversely affected by reduced light condition. The highest amount of fruit nitrogen recorded in 100% PAR level was statistically similar to that of 75% (3.06 g/100g), and 50% (2.91 g/100 g.) PAR levels and the lowest fruit nitrogen content was observed from 25% PAR level which was statistically similar with 50% PAR level. This result indicated that under shade condition, greater amount of plant nitrogen is partitioned to the leaf development.

Yield and yield components

Number of fruits per plant is the most dominant yield contributing character, which was significantly influenced by variable PAR levels (Table 5). The maximum number of fruit was found under 75% PAR level (21.83/plant) which was about 24% higher than that of 100% PAR level (18/plant). A drastic reduction of fruits per plant was recorded under 25% PAR level (6.67/plant). Similar influencing pattern in number of fruits was found in bottle gourd under reduced PAR levels (Miah, 2000). Setting of flower at higher nodes under 75% PAR compare to full sunlight and lower node number suggest less number of total flower at 75% light. So, higher number of female flower could be a possible reason for obtaining higher number of fruit. Reduction of PAR levels up to 50% did not induce any significant variation in fruit length. Fruit diameter showed decreasing trend under reduced PAR levels but the variation was not significant. This data and the visual observations lead to suggest that the fruit under 25% light

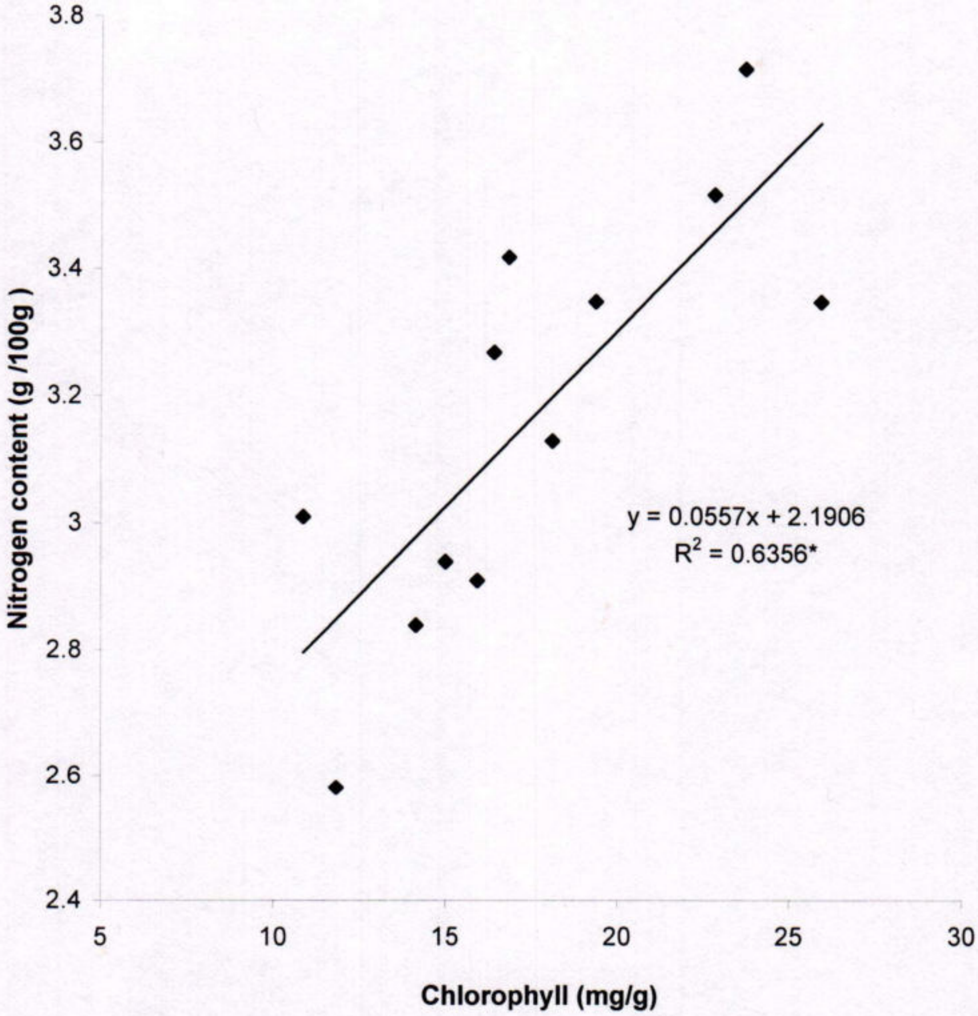

Fig.7: Relationship between chlorophyll and nitrogen content in leaf of cucumber

were mostly deformed and considered to be non-marketable. Individual fruit weight was significantly affected at different PAR levels. The heaviest individual fruit recorded under 75% PAR levels (267.30 g) was statistically similar to those under 100% (255.5 g) as well as 50% PAR level (262.7 g). However, individual fruit weight reduced markedly when the light availability was further reduced to 25% PAR level (199.3 g. Eventually there was significant influence of variation of light levels on the yield of cucumber. Among the PAR levels, the highest yield per plant was recorded under 75% PAR level (4.82 kg) and it was followed by 50% (3.52 kg) and full sunlight (3.39 kg). The lowest yield per plant was found under 25% PAR (1.38 kg). Almost similar result was found by Aidy (1984) in tomato and by Miah (2000) in bottle gourd. The total yield consequently showed similar pattern of variations among the four PAR levels as cucumber yield per plant significantly. Compare to full sunlight, the highest yield was recorded under 75% PAR level (16.09 t/ha) and the lowest yield was obtained from 25% PAR level (4.57 t/ha). The 50% PAR level produced the second highest yield (11.73 t/ha) which was statistically similar with full sunlight (11.28 t/ha). The relative fruit yield of 1.43 under 75% and 1.04 under 50% which revealed that 75% PAR level was found to exert favourable effects in cucumber production compare to that of full sunlight (Figure 8). Reduction of PAR to 25% exerted adverse changes in plants to reduce the yield of cucumber.

The relationship between yield of cucumber and light (% PAR) showed a quadratic equation as $y=0.0048x^2 + 0.6959 - 10.148$ ($R^2=0.8618$) (Figure 9) Hence, majority of total variation in the yield of cucumber can be explained by the above quadratic regression equation. The equation also stated that fruit yield of cucumber was maximum i.e. 16.37 t/ha at 73.08% PAR level and beyond this PAR level yield decreased at the rate of 0.0048 t/ha.

The results indicated that the highest yield of cucumber at 75% PAR level was attributed due to the highest number of fruit and the heaviest individual fruit. The heaviest individual fruit was positively favoured by longer fruit development period and higher total dry matter accumulation at 75 % PAR.

Table 4: Effect of different light levels on yield and yield components of cucumber

Light levels (% PAR)	Fruit numbers/plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield/ plant (kg)	Fruit yield (t/ha)
100	18.0	18.70	5.18	255.5	3.39	11.28
75	21.83	17.58	5.23	267.3	4.82	16.09
50	16.67	15.80	5.33	262.7	3.52	11.73
25	6.67	12.60	4.86	199.3	1.38	4.57
LSD (0.05)	3.19	3.81	Ns	38.31	1.19	3.96
CV (%)	10.58	11.81	8.32	11.35	18.14	18.13

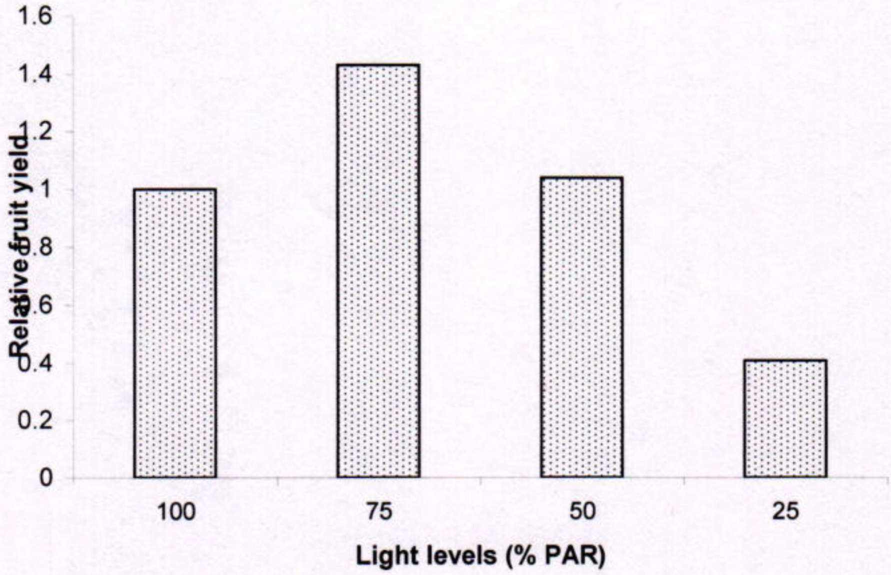

Fig.8: Relative fruit yield of cucumber as influenced by defferent light levels

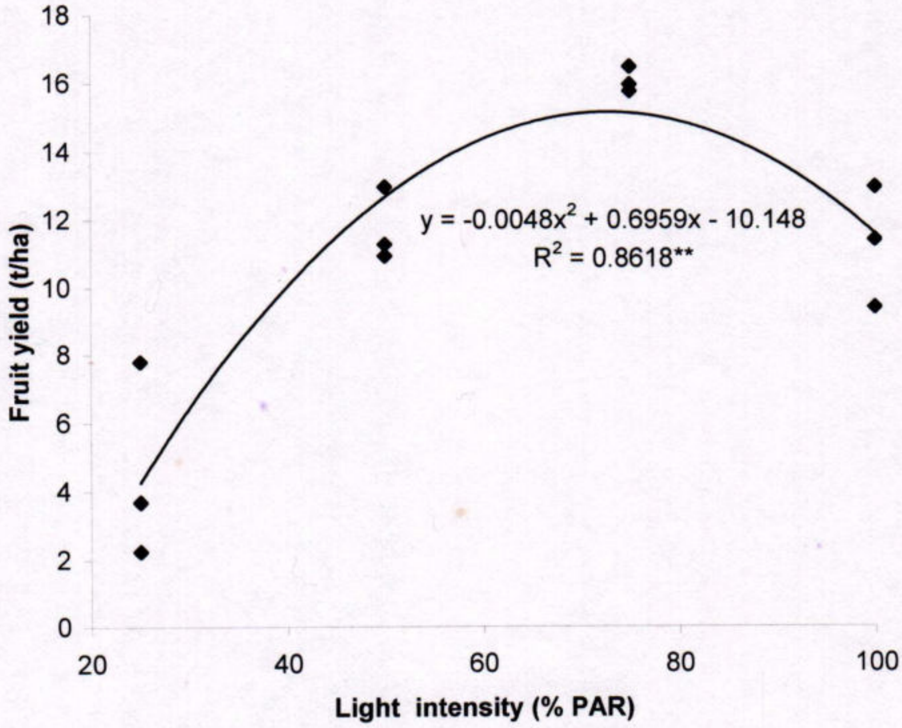

Fig 9 : Relationship between light intensity and fruit yield of cucumber.

Morpho-physiological and yield performance of ash gourd under variable light levels

Morphology

Under reduced PAR levels, the main stem and internode length of ash gourd was increased significantly compared to full sunlight condition (Table 5). The lengths of main stem and internode showed an increasing tendency with the decreasing PAR levels up to 50%. Then with further decrease of light the tendency to increase in main stem and internode length was ceased. The increase in main stem length was apparently contributed by the simultaneous increase in internode length under reduced sun light. Higher apical dominance under shade condition could be a reason of such higher main stem length (Hillman, 1984). Diameter of main stem was adversely affected by reduced PAR levels particularly at 25% PAR. The highest diameter of main stem was recorded from 100% PAR (1.85 cm), which was closely followed by 75% (1.65 cm) and 50% (1.47 cm) PAR levels showing significant differences among them. The lowest diameter was obtained from 25% PAR (1.30 cm). Reduction in stem diameter with decreasing PAR level was also reported by Tuzel and Gul (1994). Elongation of stem length was favoured by decreased stem diameter under reduced light. (Corre ,1983)

The highest number of leaf per plant was obtained from full sunlight (343), which was statistically similar with 75% PAR level (320.2). The lowest number of leaf was produced under 25% PAR level (217) and no significant variation was observed between 25% and 50% PAR levels (276.5). Significant increase in individual leaf area was observed when the PAR level was decreased from 100% (252.0 cm^2) to 50% (448.6 cm^2) PAR levels. The individual leaf area reduced significantly at 25% PAR (322.3cm^2). The earliest response of individual leaf area to decreasing light levels indicate that individual leaf area was the most sensitive morphological parameter under shade stress. Under partial shade condition stimulation of cellular expansion and cell division in leaf could be one of the possible factors that contribute to the individual leaf area increase. Schoch (1972) also reported similar findings. Specific leaf weight was significantly reduced by reducing PAR levels. Among the four PAR levels, the highest SLW was recorded from full sunlight (3.66 mg/cm^2) which did not differ with that of 75% PAR level (3.57 mg/cm^2). The significantly lowest SLW was obtained from 25% PAR level (2.27 mg/cm^2). Decrease SLW and increase in individual leaf area under decreased PAR levels apparently indicate that the low PAR levels resulted in reduction in leaf thickness. Reduced SLW of plant grown under low irradiance has been associated with reduced leaf thickness i.e. reduced palisade layers (Corre, 1983).

Crop phenology

Ash gourd grown under reduced PAR levels had longer crop duration. (Figure 10). The highest crop duration was obtained under 25% PAR level (120.7 days) whereas the shortest crop duration was observed under full sun light (101.1 days). There is no significant variation among 100%, 75% (103.3 days) and 50% (110.7 days) PAR levels in relation to crop duration.

Table 5: Stem and leaf characteristics of ash gourd in the different light conditions

Light levels (% PAR)	Main stem length (m)	Internode length (cm)	Main stem Diameter (cm)	Leaves / plant	Leaf area (cm^2/leaf)	SLW (mg/cm^2)
100	4.67	9.05	1.85	343.0	252.00	3.66
75	5.45	10.09	1.65	320.2	326.00	3.57
50	6.38	10.54	1.47	276.5	448.60	2.76
25	6.09	11.37	1.30	217.0	322.3	2.27
LSD (0.05)	0.63	1.80	0.15	64.52	47.82	0.44
CV (%)	5.6	8.78	4.77	11.16	7.10	7.17

The crop took minimum time to flower under full sunlight (23 days). Compare to full sunlight, a significant increase in time to flower was obtained at 50% PAR (28 days) as well as in 25% PAR level (22 days). Shading somewhat delayed flowering in ash gourd. Similar finding was reported by (Buge *et al.*, 1987).

Figure 11 shows that there was considerable variation in individual fruit development period under shading. Fruit development period was the shortest under full sunlight(5.87 days) and the longest was under 25% PAR level (7.72 days). Fruit development period under 75% light (6.33 days) and 50% light (7.39 days) levels were significantly different from each other. The longer duration of individual fruit under reduced sunlight, contributed to the longer crop duration by enhancing the post- anthesis growth duration. This is clearly visible at 25% PAR level compared to 100% PAR level.

Dry matter accumulation and partitioning

Dry matter accumulation in leaf, stem and fruit varied significantly under different PAR levels (Figure 12). The highest dry matter (117.6 g/plant) was recorded from full sunlight. The stem dry matter although reduced with decreasing PAR level, but the reduction was significant only at 25% PAR level compared to full sunlight. The lowest stem dry matter was produced under 25% PAR level (77.38 g/plant). Pattern of leaf dry matter reduction with decreasing PAR levels was almost similar to that of stem dry matter. The lowest leaf dry matter was produced by 25% PAR (117.1 g/plant) while the highest leaf dry matter of 237.9 g/plant was produced

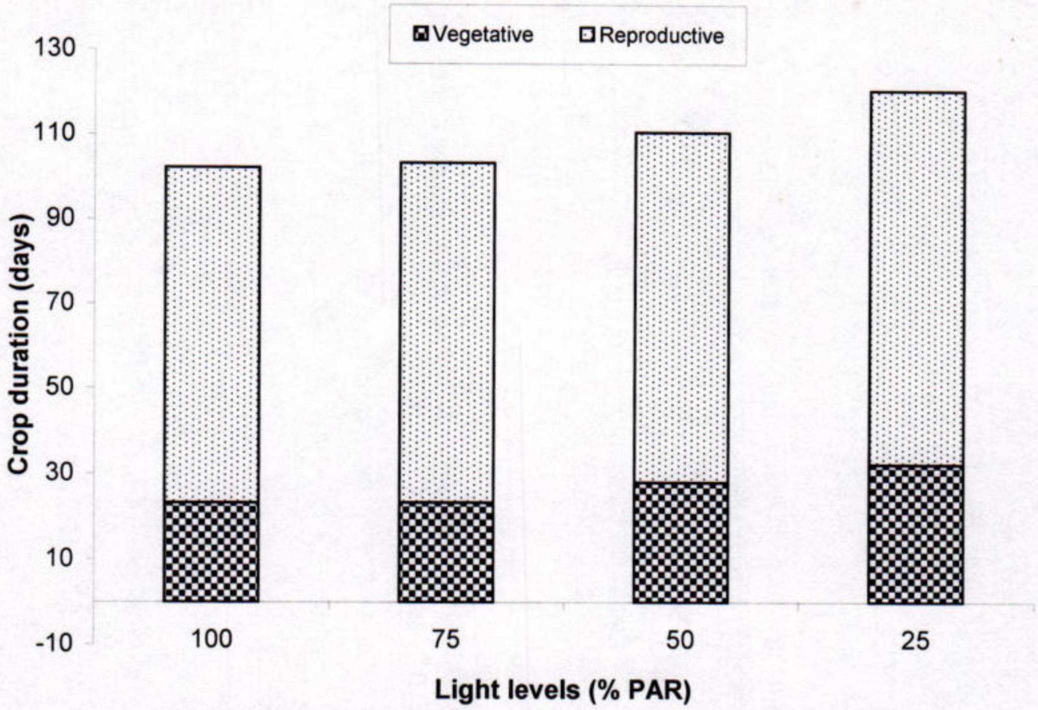

Fig.10: Duration of vegetative and reproductive phases of ash gourd as influenced by different light levels.

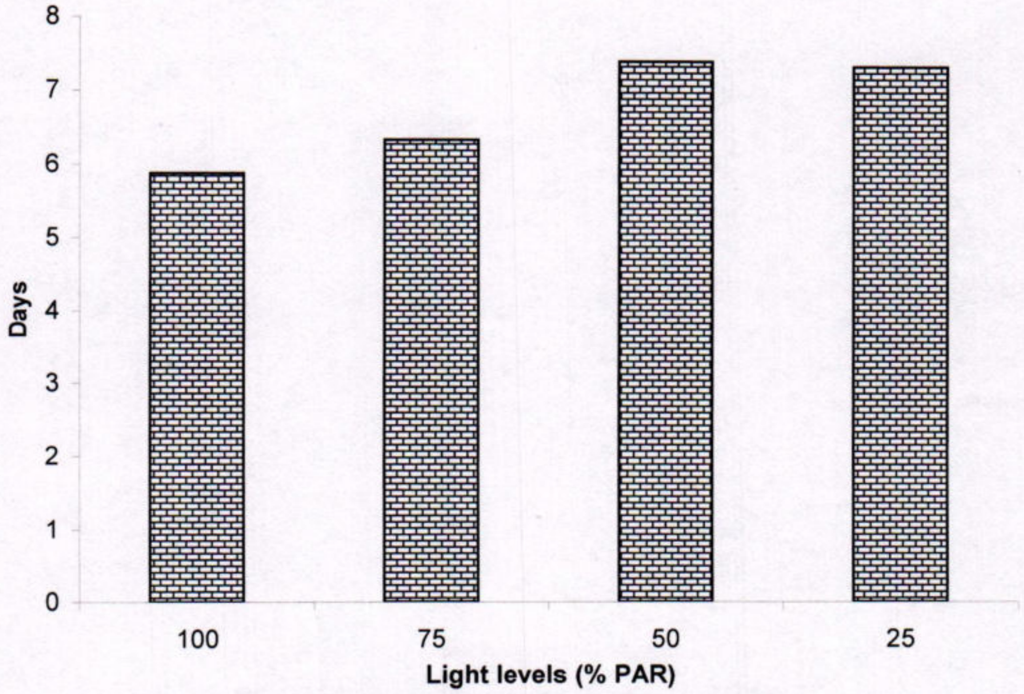

Fig.11: Fruit development period (anthesis to harvest maturity) of ash gourd as influenced by different light levels.

under full sunlight. The maximum fruit dry matter (300.3 g/plant) was harvested from full sunlight, which did not differ significantly from that of 75% PAR level (226.5 g/plant). The significantly lowest amount of fruit dry matter was obtained from 25% PAR level (64.3 g/plant) which was at par with 50% PAR (146.2g/plant). Total dry matter (TDM) production in ash gourd plant was significantly affected by varying PAR levels. The highest amount of TDM (655.7 g/plant) was obtained under full sunlight which was statistically similar to that of 75% PAR level (568.0 g/plant). Light levels below 75% PAR produced relatively small amount of TDM. The lowest TDM (258.8 g/plant) was recorded under at 25% PAR level. The result suggests that shading stress reduced the total dry matter accumulation in ash gourd. Leaf weight ratio (LWR) increased significantly under 50% PAR level (0.46) compare full sunlight (0.37)(Figure 13). The relative total dry matter production under 75%, 50% and 25% PAR levels were 0.87, 0.75 and 0.39 respectively (Figure14) which indicate that ash gourd plant does not have any relative advantages under reduced light condition in term of dry matter yield. Under 25% light ash gourd plant showed considerable reduction in total dry matter compared to full sunlight which in turn was attributed to poor leaf, stem and fruit dry weight. But higher value of LWR under reduced PAR suggests that leaf dry weight was less adversely affected relative to other organs. This is other words, could be a morpho-physiological mechanism to over come low light stress.

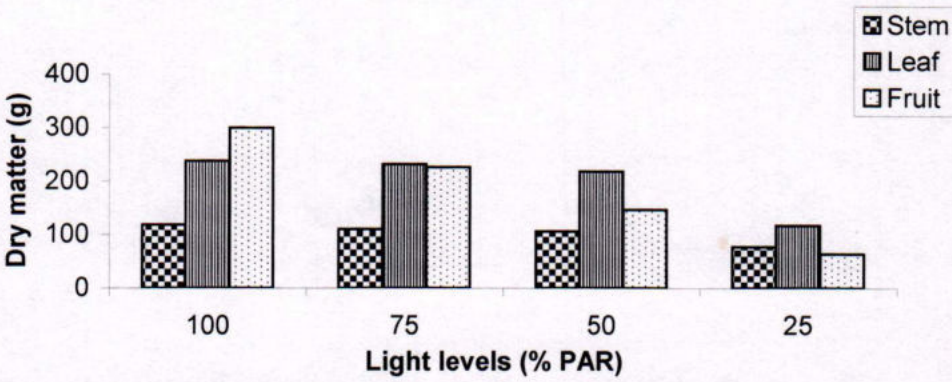

Fig.12: Distribution of dry matter in different above round parts of ash gourd in different light levels

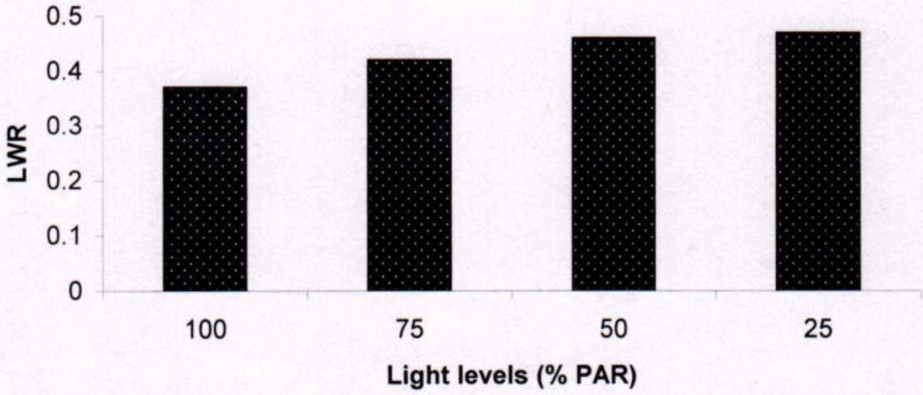

Fig.13: Leaf weight ratio of ash gourd as influenced by different light levels.

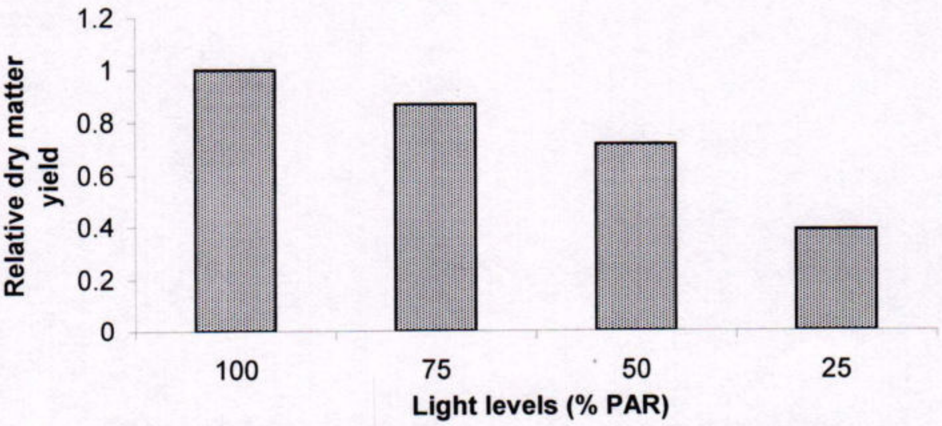

Fig.14: Relative dry matter yield of ash gourd as influenced by different reduced light levels

Leaf Pigment

Different PAR levels had significant influence on the leaf pigment content. Chlorophyll a, chlorophyll b, chlorophyll a/b ratio and β- carotene differed under different PAR levels (Table 6). The lowest chlorophyll a content was recorded under full sunlight (6.48 mg/g) which was statistically different from those recorded in other treatments. The chlorophyll a content gradually increased with the reduction in PAR levels to reach the highest quantity in leaf under 25% PAR (14.37 mg/g). Chlorophyll b also showed similar increasing pattern with the decreasing PAR levels. Significantly the highest amount of chlorophyll b was observed under 25% PAR levels (6.59 mg/g) while the lowest chlorophyll b content was under full sunlight (2.68 mg/g). The ratio of chlorophyll a/b gradually decreased (2.42 to 2.14) with the decrease of PAR levels. But this variation was non-significant. The ratio of chlorophyll a/b was the maximum in full sun light (2.42) and it was lowest under 25% PAR level (2.14). Lower ratio of chlorophyll a/b under reduced sunlight of 75% or below compared to 100% sunlight suggested the less extent of reduction of chlorophyll b than that of chlorophyll a. Chlorophyll b is considered to be a major light harvesting pigment in the chloroplasts (Helton, 1983). So, less magnitude of reduction of chlorophyll b could be desirable adjustment to maintain the photosynthetic process under light limiting condition. Total chlorophyll (a+b) content also maintained by a pattern of increasing value similar to chlorophyll a and b under reduced light condition. The highest amount of total chlorophyll was produced under 25% PAR level (20.96 mg/g). Then it gradually decreased with the increase of PAR level up to full sunlight. The lowest amount of total chlorophyll

Table 6: Chlorophyll and β-carotene content (mg/g) in the leaf of ash gourd at different light levels

Light levels (% PAR)	Chlorophyll a	Chlorophyl l b	Chlorophyll a/b	β-carotene
100	6.48	2.68	2.42	7.10
75	8.28	3.50	2.34	4.25
50	8.91	3.90	2.25	2.91
25	14.37	6.59	2.14	2.05
LSD (0.05)	1.56	0.65	Ns	0.72
CV (%)	8.23	7.83	6.55	8.86

(9.16 mg/g) was observed under full sunlight. Chen *et al.* (1994) reported that chlorophyll synthesis and accumulation in leaf was stimulated by low irradiance. A linear relationship existed between PAR levels and leaf chlorophyll content of ash gourd and expressed by equation $y = -0.1437x + 22.513$ ($R^2 = 0.8071^{**}$) where R is highly significant. The variation in the leaf chlorophyll content of ash gourd with the variation of light is well explained by the given linear regression equation (Figure 15).

Plant grown under reduced light condition had significantly lowered the amount of β-carotene in then leaves. The highest amount of β-carotene in leaf was recorded under full sunlight (7.1 mg/g) followed by 75% (4.25 mg/g), 50% (2.91 mg/g) and 25% (2.05 mg/g) PAR levels. The result was in agreement with that of Adams and Adams (1992) as they also found a reduction of β-carotene under shaded condition in ash gourd although α-carotene content was increased.

Nitrogen content

Leaf, stem and fruit nitrogen was significantly influenced by different reduced PAR levels (Table 7). The highest stem nitrogen was recorded under full sunlight (1.94g/100 g). The lowest stem nitrogen (1.69g/100g) was observed under 25% PAR levels. The amount of leaf nitrogen was the lowest under full sunlight (2.38 g/100 g) and it then increased slightly under 75% PAR level (2.49 g/100 g) but the difference was not significant. The highest amount of leaf nitrogen was recorded from 25% light treatment (2.89 g/100 g) which was statistically similar to that of 50% PAR level (2.72 g/100 g) but significantly higher compared to leaf nitrogen content under any other higher levels of light.

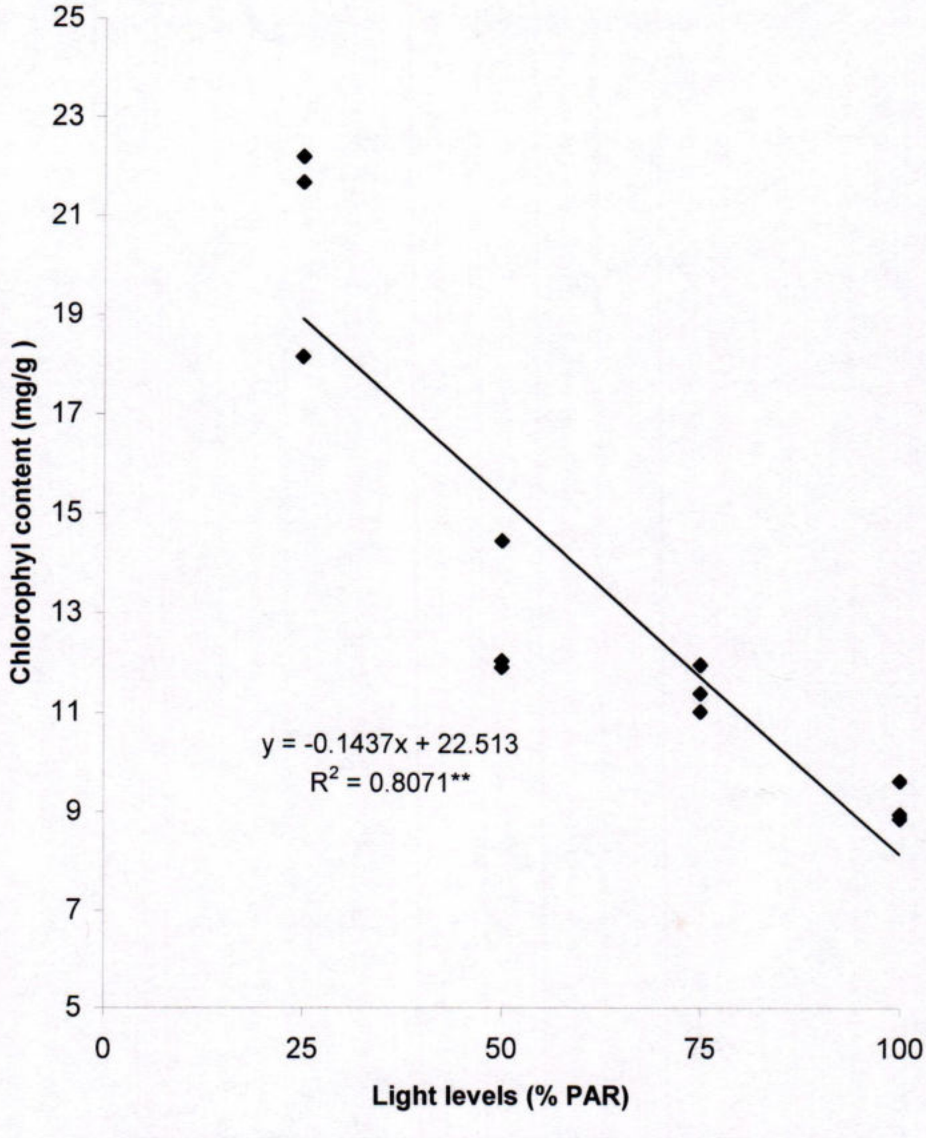

Fig.15: Relationship between different light levels and chlorophyll content in ash gourd leaf

A linear relationship between leaf chlorophyll and leaf nitrogen content was existed and estimated as $y = 0.0405x + 2.0593$ ($R^2=0.6288^{**}$) where the R^2 value is significant. The relationship indicates that the variation in leaf nitrogen content in ash gourd depends on leaf chlorophyll content (Figure 16). Under reduced light conditions the ash gourd leaves were appeared to be deep green in colour compared to full sunlight. The increased chlorophyll content under reduced sunlight induced deep green colour to the leaf which, in turn, resulted in higher foliar nitrogen content.

Fruit nitrogen content significantly decreased due to reduced light condition. The highest amount of fruit nitrogen was recorded in 100% PAR level (1.69 g/100 g) which was statistically similar to that of 75% (1.67 g/100 g), and 50% (1.55 g/100 g) PAR levels. The lowest fruit nitrogen content was observed from 25% PAR level (1.45 g/100 g) which was statistically similar with 50% PAR level. This result indicated that plant partitioned greater amount of nitrogen to leaf development under shade condition.

Yield and yield components

Number of fruits per plant gradually decreased with the decreased of PAR levels but the reduction was found significantly only at 25% PAR compared to 100% PAR (Table 8). The maximum number of fruits (17/plant) was found under 100% PAR level which was statistically similar to 75% (15.67/plant) and 50% (13.33/plant) PAR levels. A rapid reduction of fruits per plant was recorded under 25% PAR level which eventually resulted in the lowest fruit number (6.00/plant).

Table 7: Nitrogen content in the above ground parts of ash gourd at different light levels

Light levels (% PAR)	Nitrogen content (g/100g)		
	Stem	Leaf	Fruit
100	1.94	2.38	1.69
75	1.92	2.49	1.67
50	1.73	2.72	1.55
25	1.69	2.89	1.45
LSD (0.05)	0.15	0.28	0.19
CV (%)	4.16	5.29	5.01

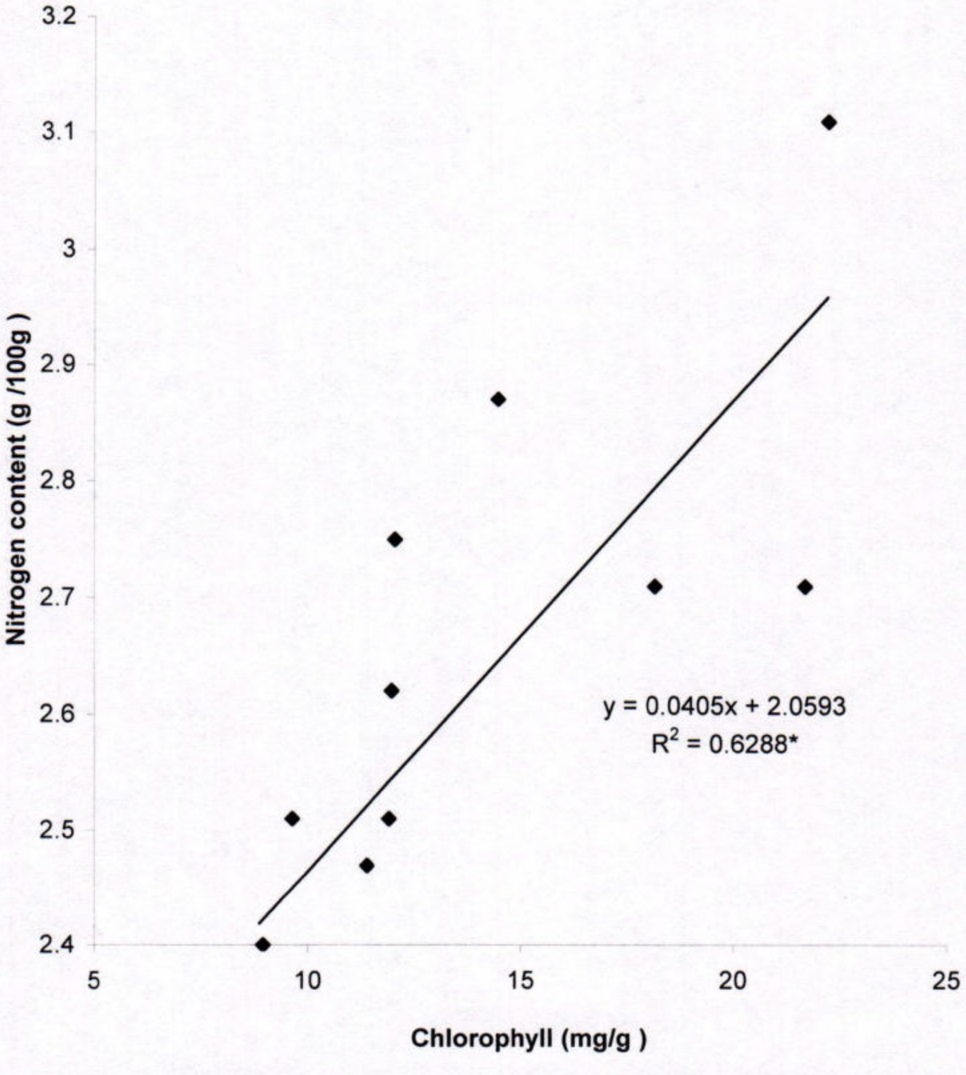

Fig.16: Relationship between chlorophyll and nitrogen content in leaf of ash gourd

Similar influencing pattern in number of fruits was found in eggplants under reduced PAR levels (Miah, 2001). These results indicate that ash gourd can be grown even under 50% PAR level without significant reduction in number of fruit per plants as compare to the open field. Ash gourd exhibited significantly longest fruit (20.93 cm) under full sunlight. The shortest fruit (15.44 cm) was found under 25% PAR level which was statistically similar to that of 50% PAR levels (16.97 cm). Fruit diameter showed decreasing trend under reduced PAR levels and varied from 8.19 cm to 10.12 cm under variable light treatment. But this variation was not significant. The fruit under 25% light were mostly deformed and non-marketable. The heaviest individual fruit was recorded under full sunlight (743.5 g). However, it reduced markedly when the light availability was further reduced to 50% PAR level (540.3g). Which was statistically similar to 25% PAR levels (570.3 g).

There was significant influenced on the yield of ash gourd under different PAR levels. Among the four PAR levels the highest yield per plant was recorded under 100% PAR level (6.30 kg) which was closely followed by 75% PAR (5.24 kg). Both 50% and 25% PAR levels gave the lowest fruit yield of 3.58 and 1.75kg/plant respectively. The lowest yield per plant was found under 25% PAR level (1.75 kg). Almost similar result was found by (Miah, 2001) in eggplant. The highest yield of ash gourd under 100% PAR level may be attributed by the highest number of fruit as well as the heaviest individual fruit size. The yield was recorded under full sunlight (21.03t/ha) was statistically similar to that of the 75% PAR level (17.46 t/ha). Significantly lowest fruit yield was harvested from 25% PAR (5.39t/ha) which was statistically similar with full sunlight and 50% PAR levels (11.63 t/ha). The relative fruit yield of 0.83 under 75% and 0.57 under 50% revealed that full sunlight was found to exert favourable effects in ash gourd production compare to that of different reduced PAR levels (Figure 17). But ash gourd plant gave only 26% yield of full sunlight treatment under 25% PAR levels. It means that shade below 75% light exerted adverse changes in plants that caused reduction in yield of ash gourd. The yield of ash gourd and PAR levels showed a significant linear relationship expressed by an equation $y = 0.2091x + 0.8933$ ($R^2=0.8021^{**}$). (Figure 18).

Finally yield did not reduce significantly at 75% PAR. This happened because of comparable fruit number and individual fruit size under 100% and 75% PAR. Further reduction of PAR to 50% or below gave a significant reduction in fruit yield mainly because of smaller fruit number and fruit size. Reduction of PAR to 75% did not bear any significant changes in leaves per plant, individual leaf area and SLW. Besides the reduction of PAR resulted in increased duration of individual fruit development. However, all these changes in ash gourd did not allow to cause reduction in fruit number and individual fruit weight as well as fruit yield at 75% PAR level.

Table 8: Effect of different light levels on yield and yield components of ash gourd

Light levels (% PAR)	Fruit numbers /plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield/ plant (kg)	Fruit Yield (t/ha)
100	17.00	20.93	8.1	743.5	6.30	21.03
75	15.67	18.48	8.86	673.0	5.24	17.46
50	13.33	16.97	9.93	5.40.3	3.58	11.63
25	6.00	15.44	10.12	570.3	1.75	5.39
LSD(0.05)	4.30	1.61	**Ns**	115.3	2.43	7.93
CV (%)	5.52	16.57	8.24	11.21	21.40	21.46

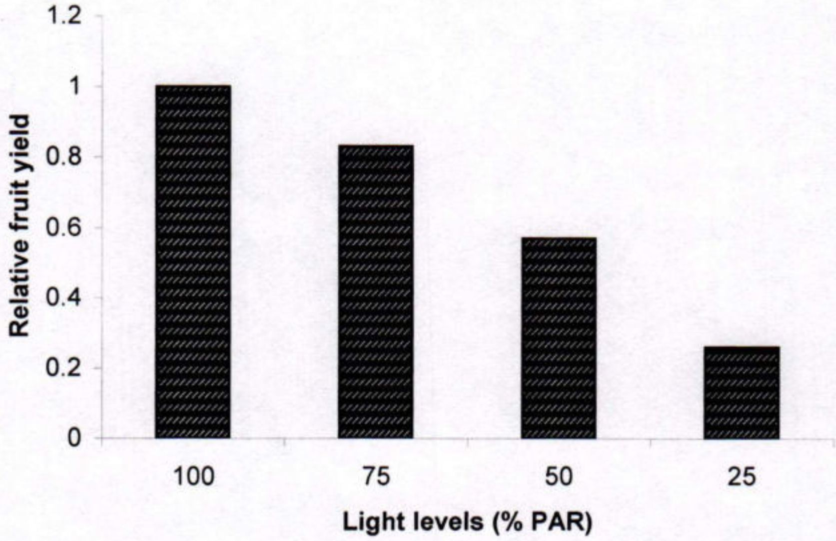

Fig.17: Relative fruit yield of ash gourd as influenced by defferent light levels

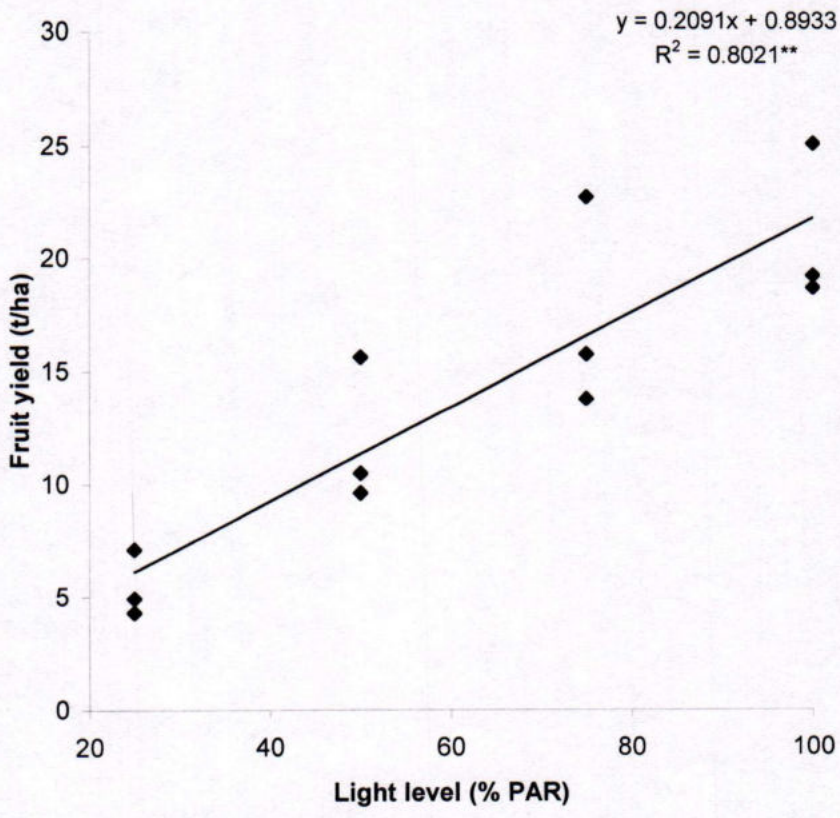

Fig 18: Relationship between light levels and fruit yield of ash gourd.

Morpho-physiological and yield performance of sponge gourd under variable light levels.

Morphology

The response of main stem length of sponge gourd was not significantly influenced with the reduction in PAR levels (Table 9). Significantly higher internode length under 75% PAR treatment (19.90 cm) compared to 100% PAR (17.17cm) was recorded in sponge gourd. The longest internode was found at 50% PAR level. There was no significant variation between internode length of 25% (20.58 cm) and 50% PAR levels. The shortest length (17.17cm) was obtained under full sunlight. The highest diameter of main stem was recorded from 100% (1.32 cm) which did not differ from that of 75% PAR level (1.24 cm). The lowest diameter was obtained from 25% PAR level (0.82 cm) which was statistically different from 50% light (0.98 cm). Reduction in stem diameter with decreasing PAR level was also reported by Tuzel and Gul (1994).

The highest number of leaves per plant was obtained from full sunlight (634.8), which was statistically similar with 75% PAR levels (575.8 cm). The lowest number of leaf was produced under 25% PAR level (345) and there was no significant variation observed between 25% and 50% (453.3). Significant increase in individual leaf area was observed when the PAR level was decreased from 100% (189.6 cm^2) to 50% (372.3 cm^2) PAR levels. Under partial shade condition stimulation of cellular expansion and cell division in leaf could be one of the possible factors that contribute to the individual leaf area increase. Schoch (1972) also

Table 9: Stem and leaf characteristics of sponge gourd in the different light conditions

Light levels (% PAR)	Main stem length (m)	Internode length (cm)	Main stem diameter (cm)	Leaves / plant	Leaf area (cm^2/leaf)	SLW (mg/cm^2)
100	14.04	17.17	1.32	634.8	189.6	2.91
75	15.23	19.90	1.24	575.8	255.8	2.80
50	17.04	20.86	0.98	453.3	420.8	2.46
25	13.2	20.58	0.82	345.0	372.3	2.20
LSD(0.05)	3.22	2.70	0.13	103.6	100.3	0.25
CV (%)	10.84	9.48	5.41	10.28	16.21	4.91

reported similar findings. Specific leaf weight (SLW) was also significantly reduced by reducing PAR levels. Among the four PAR levels, the highest SLW was recorded from full sunlight (2.91 mg/cm^2) which was statistically identical to that of 75% PAR level (2.80 mg/cm^2). Significantly lowest SLW was obtained from 25% PAR level (2.20 mg/cm^2). Decreased SLW under decreased PAR level apparently indicated that the low PAR levels resulted in reduction in leaf thickness. Plant grown under low irradiance has reduced SLW which was associated with reduced leaf thickness i.e. reduced palisade layers Corre (1983).

Crop phenology

Crop duration increased significantly under reduced light condition (Figure 19). The highest crop duration was recorded under 25% PAR levels (192.7 days) whereas the shortest crop duration was observed under full sun light (148.8 days). There is no significant variation between 75% (163.7 days) and 50% (182.8 days) PAR levels in respect of crop duration.

The shortest time to flower was recorded under full sunlight (63.67 days). Compare to full sunlight, 50% PAR level (84.67 days) and 25% PAR level (100.20 days) showed significant increase in time to flower. Plant grown under full sunlight took shortest period to reach the first flowering stage. It means that shading somewhat delayed flowering. Similar finding was reported by Buge *et al.*,(1987). It is clear here that the reproductive period (first flower to maturity) was longer than vegetative period under shading condition. Fruit development period was the shortest (5.72 days) under full sunlight which was statistically similar with 75% (6.44) and

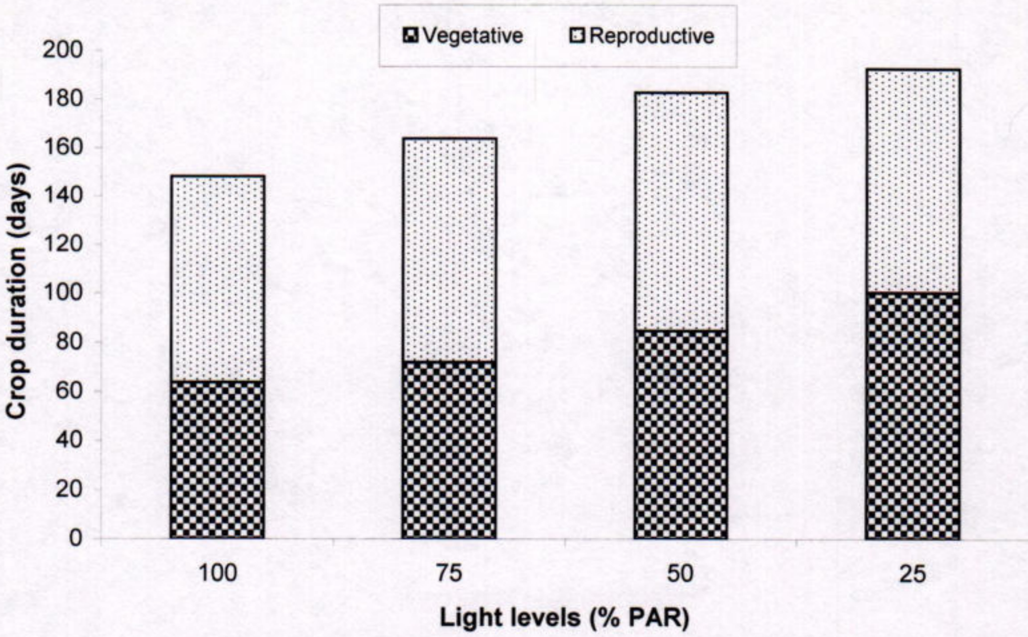

Fig.19: Duration of vegetative and reproductive phases of sponge gourd as influenced by different light levels.

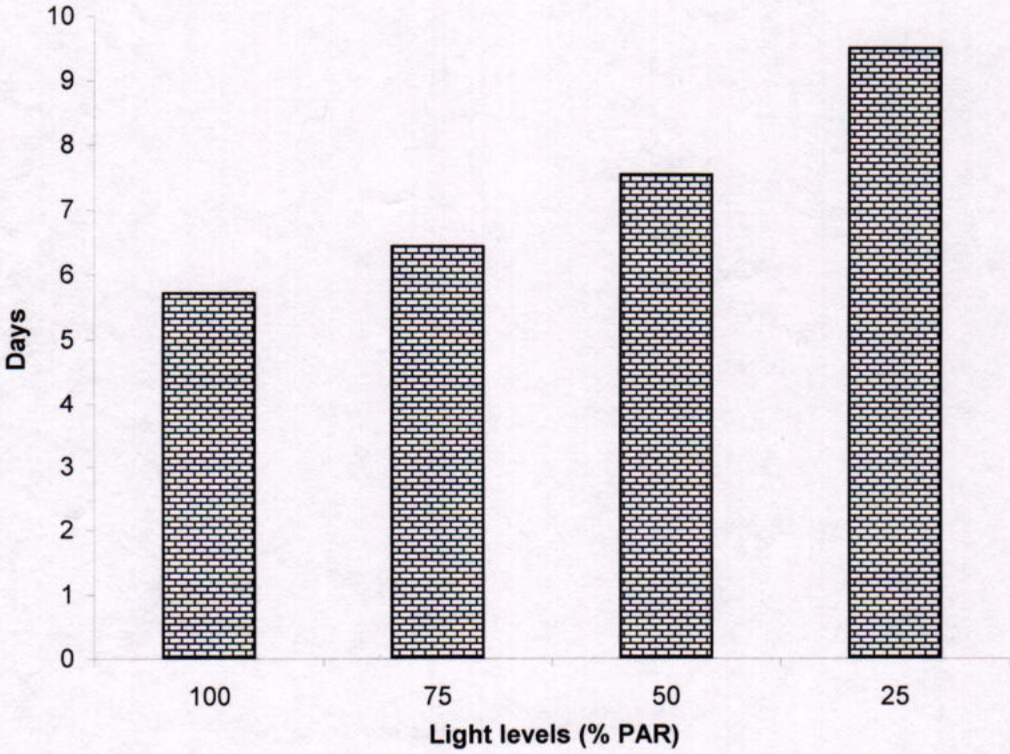

Fig.20: Fruit development period (anthesis to harvest maturity) of sponge gourd as influenced bydifferent light levels.

50% (7.55) PAR levels and the longest (9.52 days) was under 25% PAR level (Figure 20). The longer duration of individual fruit under reduced sunlight, contributed to the longer crop duration by enhancing the post- anthesis growth duration. This is clearly visible at 25% PAR level compared to 100% PAR level

Dry matter accumulation and partitioning

Dry matter accumulation in leaf, stem and fruit were significantly decreased due to reduced PAR levels (Figure 21). At 75% PAR level, the maximum stem dry matter (293.0 g/plant) was harvested which was statistically similar to full sunlight (247.9 g) and 50% PAR levels (274.0 g). The stem dry matter although reduced with decreasing PAR level, but the reduction was significant only at 25% PAR level compared to other PAR levels. The lowest stem dry matter was produced under 25% PAR level (226.6 g/plant). Leaf dry matter reduced gradually with decreasing PAR levels. The lowest leaf dry matter was produced by 25% PAR level (245.1 g/plant). The highest leaf dry matter of 254.2 g/plant was produced under full sunlight. The reduction of leaf dry matter was significant only at 25% PAR level. However, fruit dry matter under full sunlight (336.1 g/plant) was found to be higher compared to fruit dry matter under different reduced PAR levels. Under 75% PAR level, leaf and fruit dry matter decreased compared to that of full sunlight whereas stem dry matter increased. It revealed that dry matter partitioned to the stem under 75% PAR level was higher compare to other treatments. Total dry matter (TDM) production in sponge gourd plant was significantly affected by varying PAR levels (Table 12). The highest amount of TDM (965.2 g/plant) was obtained under full sunlight which was statistically similar to that of 75% PAR level (902.4 g/plant). Light below 75% PAR level produced relatively small amount of TDM. The TDM recorded under at 25% PAR level (484.7 g/plant) was the lowest. The result also suggested that higher light exerted favourable influence on the total dry matter accumulation in sponge gourd and with increasing the shade stress total dry matter production decreased drastically. Reduced PAR levels had significant influence on leaf weight ratio (Figure 22). The LWR was lower at 100% and 75% PAR levels, which then increased at 50% PAR level (0.51). There is no significant variation between 50% and 25% (0.51) PAR levels. Reduction of PAR levels from 100% to 75% did not affect the percentage distribution of total dry matter to leaf. But at 50% and 25% PAR level major dry matter was retained in leaf in expense of the total dry matter. The lower relative total dry matter (0.93 to 0.50) under different reduced PAR levels (1.05) compared to full sunlight (Figure 23) sponge gourd cultivation is not suitable under reduced light condition. Under 25% light sponge gourd plant showed considerable reduction in total dry matter compared to full sunlight which in turn was attributed to poor leaf, stem and fruit dry weight. But high LWR at 25% light suggests that LWR was less adversely affected relative to other components.

Leaf pigment

The pigment contents viz. chlorophyll a, chlorophyll b, chlorophyll a/b ratio and β- carotene differed under different PAR levels (Table 10). The lowest chlorophyll a content was recorded under 100% light (6.74 mg/g) which was statistically similar to 75% PAR levels (8.25 mg/g) but different from other

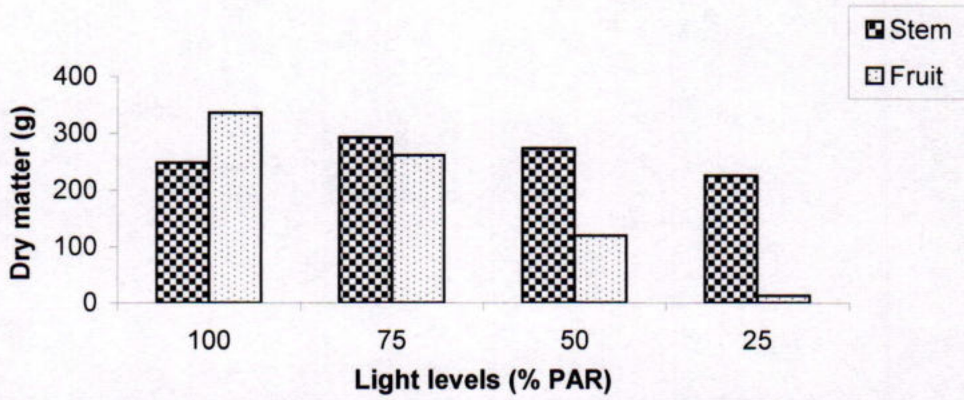

Fig. 21: Distribution of dry matter in different above ground parts of sponge gourd in different light levels

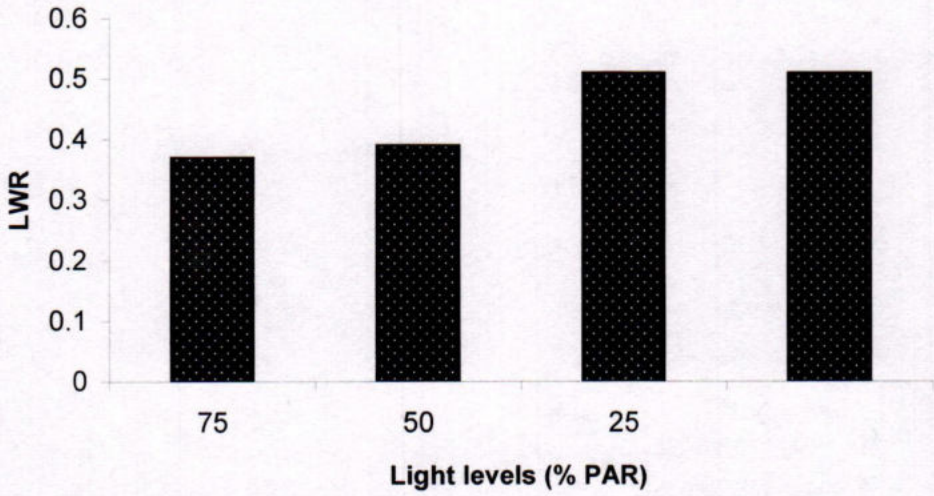

Fig. 22: Leaf weight ratio of sponge gourd as influenced by different light levels.

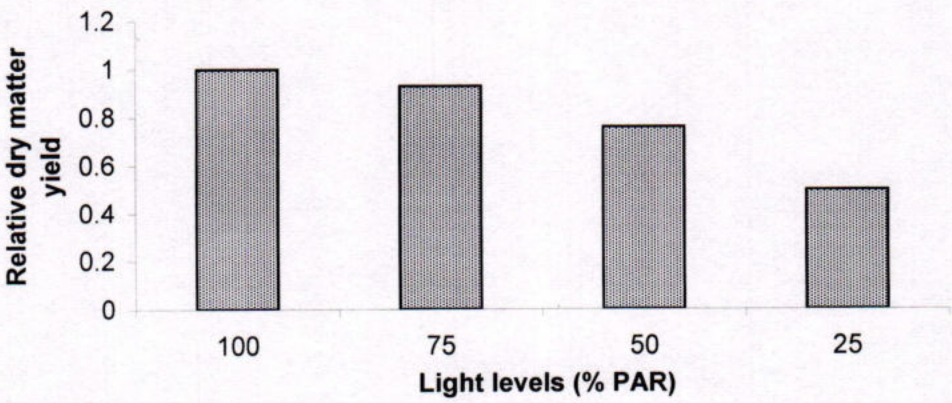

Fig. 23: Relative dry matter yield of sponge gourd as influenced by different reduced light levels

treatments. The chlorophyll a content progressively increased with the reduction of PAR levels and the highest quantity of chlorophyll a in leaf was obtained from 25% light (14.62 mg/g). Chlorophyll b also showed similar increasing pattern with the decreasing PAR levels. Significantly the highest amount of chlorophyll b was observed under 25% PAR levels (6.12 mg/g) while the lowest chlorophyll b content was under full sunlight (2.38 mg/g). But there is no significant variation between full sunlight and 75% PAR levels (3.14 mg/g). The chlorophyll a/b ratio varied from 2.15 to 2.53 under different PAR levels but the variation was not significant. The highest a/b ratio was recorded from full sunlight where as the lowest was recorded from 25% PAR level. Total chlorophyll (a+b) content also maintained by a pattern of increasing value similar to chlorophyll a under reduced light condition. The highest amount of total chlorophyll was produced under 25% PAR levels (21.40 mg/g). Then it gradually decreased with the increase in PAR level up to full sunlight. The lowest amount of total chlorophyll was recorded under full sunlight (9.90 mg/g). The lower light intensity due to shading caused an increase in synthesis and accumulation of chlorophyll (Chen *et al.*, 1994). A linear relationship between PAR levels and leaf chlorophyll content of sponge gourd was found to be highly significant (R^2= 0.7741**) where R is highly significant (Figure 24). The variation in the leaf chlorophyll content of sponge gourd with the variation of light is well explained by the relationship.

Plant grown under reduced light condition had significantly lowered the amount of β-carotene in the leaves. The highest amount of β-carotene in leaf was

Table 10: Chlorophyll and β-carotene content (mg/g) in the leaf of sponge gourd at different light levels

Light levels (% PAR)	Chlorophyll a	Chlorophyll b	Chlorophyll a/b	β-carotene
100	6.74	2.38	2.53	3.62
75	8.25	3.14	2.62	2.40
50	9.42	4.00	2.37	1.67
25	14.62	6.12	2.15	1.27
LSD(0.05)	2.25	1.25	ns	0.25
CV (%)	11.53	15.61	9.68	5.61

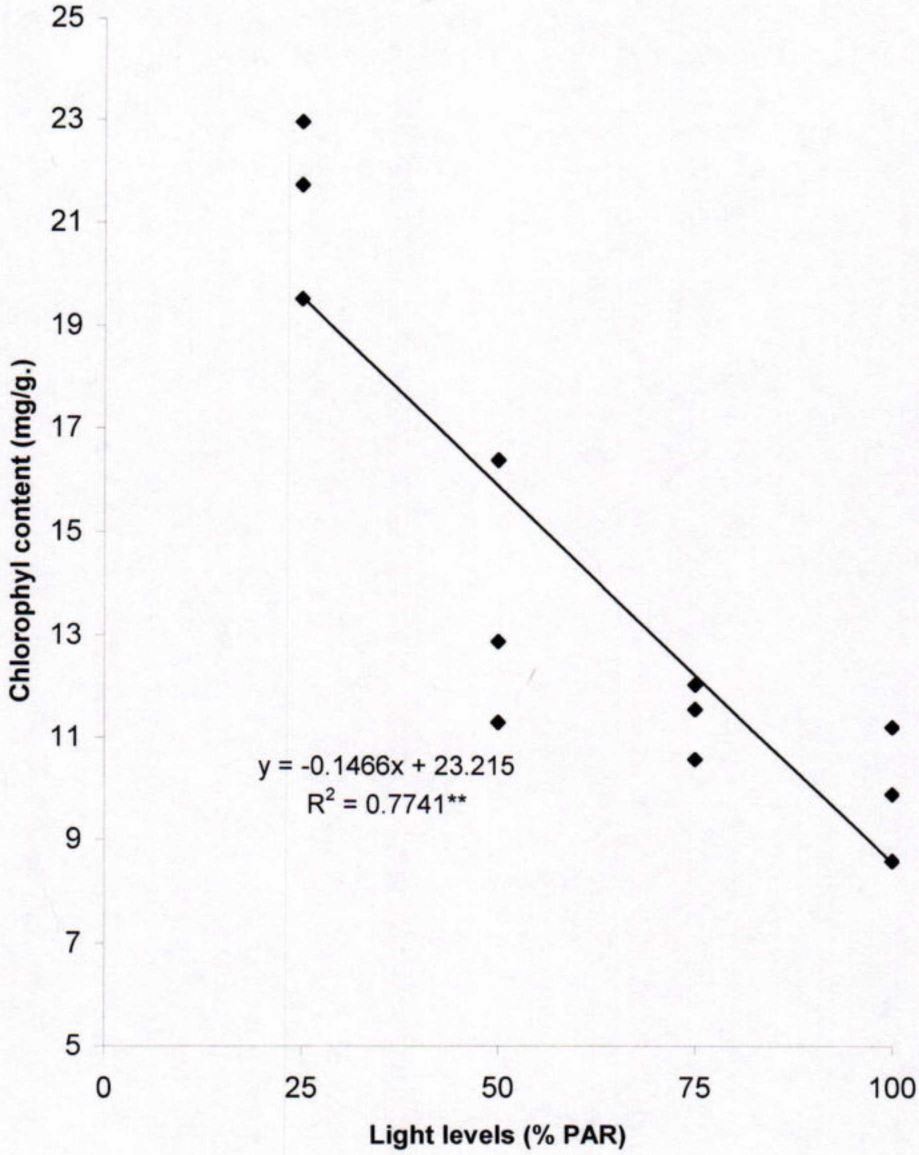

Fig.24: Relationship between different light levels and chlorophyll content in sponge gourd leaf

recorded under full sunlight (3.62 mg/g) followed by 75% (2.40 mg/g), 50% (1.67 mg/g) and 25% (1.27 mg/g) PAR levels. But there was no statistical difference among full sunlight 75% and 50% PAR levels in respect of β-carotene content. Adams (1992) reported that β-carotene content in leaf decreased under shaded condition but the amount of α-carotene was increased.

Nitrogen content

Stem nitrogen varied from 2.07 g to 1.65 g per 100 g of dry tissue under variable light treatments (Table11). But this variation was found to be non-significant. The amount of leaf nitrogen was the lowest under full sunlight (2.68 g/100 g) and it then increased slightly under 75% PAR levels (2.79 g/100 g) but the difference was not significant. The highest amount of leaf nitrogen was recorded from 50% PAR level treatment (3.24 g/100 g) which was statistically similar to that of 25% PAR level (3.07 g/100 g) but significantly higher compared to leaf nitrogen content under 75% PAR (2.79 g/100g) and 100% PAR (2.68g/100g).

There existed a linear relationship between leaf chlorophyll and leaf nitrogen content estimated as $y = 0.0368x + 2.4216$ (R^2=0.3835). Where the R^2 value is non-significant (Figure 25). The relationship indicate that the variation in leaf nitrogen content of sponge gourd was very weak due to reduced PAR level i.e. leaf chlorophyll played insignificant role in contributing toward leaf nitrogen content of sponge gourd.

Table 11: Nitrogen content in the above ground parts of sponge gourd at different light levels

Light levels (% PAR)	Nitrogen content (g/100g)		
	Stem	Leaf	Fruit
100	2.07	2.68	3.32
75	1.97	2.79	3.08
50	2.04	3.24	2.89
25	1.65	3.07	2.66
LSD (0.05)	Ns	0.36	0.62
CV (%)	11.77	6.08	8.33

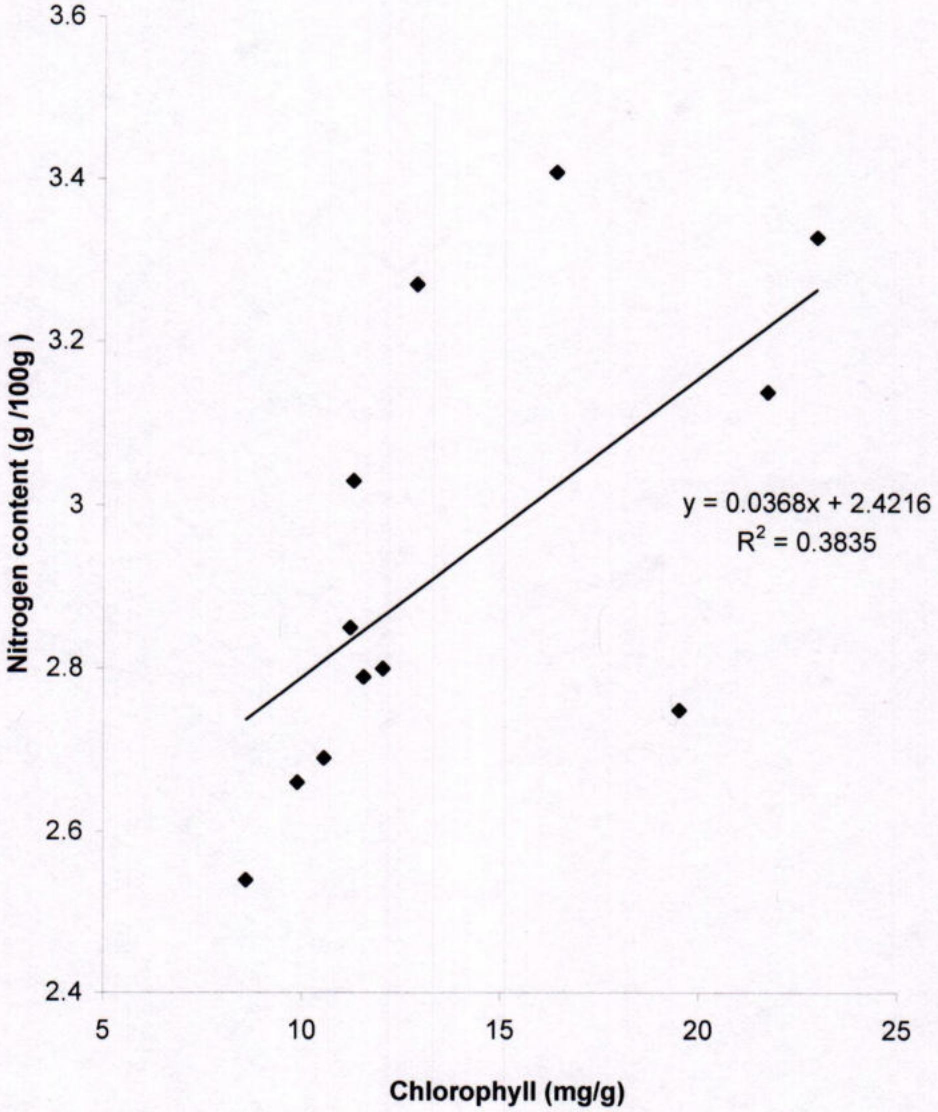

Fig.25: Relationship between chlorophyll and nitrogen content in leaf of sponge gourd

Fruit nitrogen content also adversely affected by reduced light condition. The highest amount of fruit nitrogen recorded under full sunlight (3.32 g/100 g) was statistically similar to that of 75 % (3.08 g/100 g), and 50% (2.89 g/100 g) and the lowest fruit nitrogen content was observed from 25% PAR level (2.66 g/100 g) which was statistically similar with 75% and 50% PAR level. This result indicated that under partial shade condition, leaf accumulates relatively higher amount of nitrogen.

Yield and yield components

Number of fruits per plant is the most important yield contributing characters, which was significantly influenced by different PAR levels (Table 12). The maximum number of fruit (39.33/plant) was found under full sunlight and reduced gradually with the reduction of PAR levels. The lowest fruit number was recorded under 25% PAR level (2.83 /plant) which was statistically different from 50% PAR level (10/plant). Similar influencing pattern in number of fruits was observed in eggplant under reduced PAR levels (Miah, 2001). These results revealed that sponge gourd can not be suitable for growing 50% PAR level because number of fruit per plant reduced drastically as compare to the open field. Plant grown under full sunlight produced the longest fruit (22.41cm) whereas the shortest fruit was obtained under 25% PAR levels (17.75 cm). Fruit length did not defer significantly from that of 50% PAR levels (18.08 cm) There was no significant variation among different PAR levels in respect of fruit diameter. This data and the visual observations lead to suggest that the fruit under 25% light were mostly deformed and appear to non-marketable. Individual fruit weight was significantly affected at different PAR levels. The heaviest individual fruit (190.30 g) was recorded under 100% PAR level which varied significantly from 75% (158.5 g) as well as 50% PAR levels (151.4 g) and there was no significant variation among 75% and 50% and 25% (144.0 cm) PAR levels.

There was significant influence on the yield of sponge gourd under different PAR levels. Among the four PAR levels the highest yield per plant was recorded under full sunlight (7.47 kg) which differed markedly from 75% (5.63 kg). The lowest yield per plant was found under 25% PAR (0.44 kg) which was statistically similar to that of 50% PAR level (1.32kg). Almost similar result was found by (Miah, 2001) in eggplant. The highest number of fruit as well as the heaviest individual fruit size may attribute highest yield of sponge gourd at 100% PAR level. The fruit yield per hectare consequently showed almost similar pattern of variations among the four PAR levels as sponge gourd fruit yield per plant. The highest yield was recorded under 100% PAR level (24.90 t/ha) and the lowest yield was obtained from 25% PAR level (1.45 t/ha). The 75% PAR levels produced the second highest yield (18.78 t/ha) which was statistically different from that of full sunlight.

Table 12: Effect of different light levels on yield and yield components of sponge gourd

Light levels (% PAR)	Fruit numbers /plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield/ plant (kg)	Fruit yield (t/ha)
100	39.33	22.41	4.58	190.3	7.47	24.90
75	33.17	21.35	4.20	158.5	5.63	18.78
50	10.00	18.08	4.19	151.4	1.32	4.40
25	2.83	17.75	4.05	144.0	0.44	1.45
LSD(0.05)	2.96	2.18	Ns	27.75	1.57	5.08
CV (%)	6.39	6.62	14.97	11.39	14.49	14.56

The relative fruit yield of 0.75 under 75% PAR and 0.18 under 50% PAR revealed that full sunlight was found to exert favourable effects on sponge gourd production compare to that of reduced PAR levels (Figure 26). But under 25% PAR level sponge gourd plant gave only 6% yield compare to full sunlight treatment.

The relationship between yield of sponge gourd and PAR levels (% PAR) showed a linear equation as $y = 0.3389x - 8.8$ (R^2=0.9091**) which indicated that majority of total variation in the yield of sponge gourd can be explained by the above linear regression equation (Figure 27).

The overall results suggested that fruit yield decreased significantly at 75% PAR and below because of longer vegetative period lowered individual leaf area adjustment and less fruit setting.

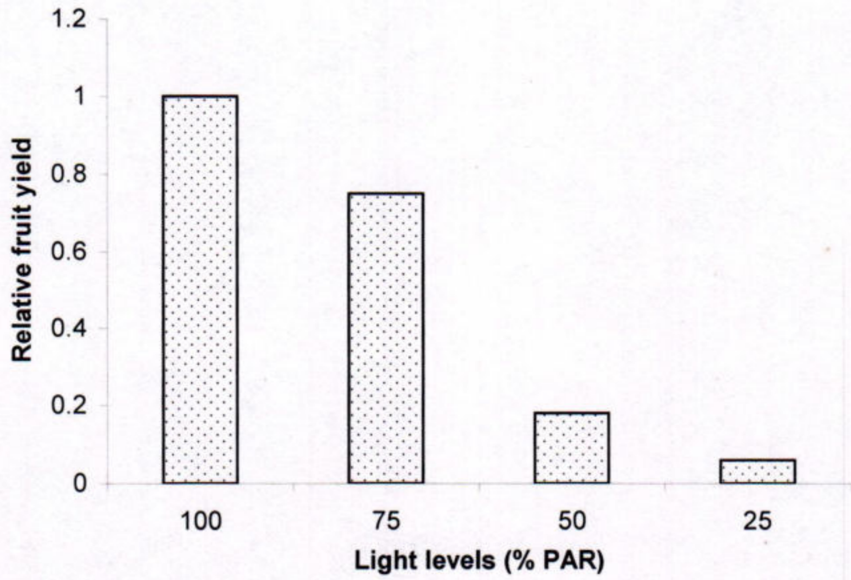

Fig.26: Relative fruit yield of sponge gourd as influenced by defferent light levels

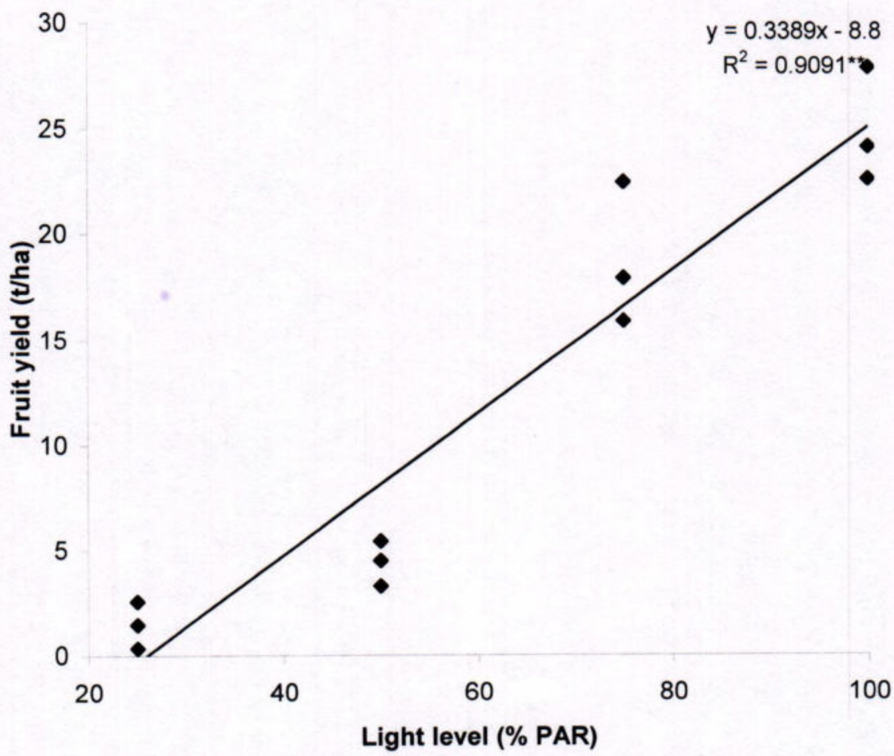

Fig 27: Relationship between light levels and fruit yield of sponge gourd.

Morpho-physiological and yield performance of yard long bean under variable light levels.

Morphology

Main stem length of yard long bean increased significantly when PAR levels were reduced to 50% or below. (Table 13). But there was no significant variation in main stem length between 50% (5.23m) and 25% (5.00 m) PAR levels. Similarly higher length of main stem was also observed under reduced sun light in chick pea (Murshed,1996). Yard long bean plant exhibited significantly higher internode length in the treatments consisted of 50% or below PAR levels. The longest internode length at 25% PAR level (22.68 cm) and the shortest length was obtained under full sunlight (13.75 cm). Under reduced sun light (50% or below) the increase in individual internode length resulted increased main stem length. This was probably due to higher apical dominance under shade condition (Hillman, 1984). Diameter of main stem decreased significantly due to reduced PAR levels. Highest diameter of main stem was recorded from 100% (1.23 cm) as well as 75% PAR level (1.16 cm). Whereas the lowest diameter was obtained from 25% PAR level (0.80 cm). Similar reduction in stem diameter in tomato with decreasing PAR level was also reported by Tuzel and Gul (1994). Corre (1983) reported that stem length increased at the expense of root growth and stem girth.

The leaf numbers/plant was significantly reduced by shade treatments. The highest number of leaf /plant was obtained from 75% PAR level (402.2) which was statistically similar with full sunlight (399.8). The lowest number of leaf was produced under 25% PAR level (219.7) and no significant variation was observed between 25% and 50% (303.8). Significant increase in individual leaf area was observed when the PAR level was decreased from 100% (99.3 cm^2) to 25% (279.9 cm^2) PAR levels. Under partial shade condition stimulation of cellular expansion and cell division in leaf could be one of the possible factors that contribute to the individual leaf area increase. Schoch (1972) also reported similar findings. Among the four PAR levels, the highest SLW was recorded from full sunlight (2.53 mg/cm^2) which was statistically identical to that of 75% PAR level (2.34 mg/cm^2). Significantly lowest SLW was obtained from 25% PAR level (1.74 mg/cm2). By decreasing SLW under decreased PAR levels plants ensured the reduction in leaf thickness. Leaves developed in shade contained reduced palisade layers (Corre, 1983). Nygren and Kellomaki (1983) also reported hat thickness of leaf mesophyll was reduced by increasing shading.

Crop phenology

Crop duration was significantly increased by reduced light condition (Figure 28). The highest crop duration was obtained under 25% PAR levels (127.7 days) whereas the shortest crop duration was observed under full sunlight (94.67 days). There is no significant variation between 75% (101.20 days) and 100% (94.67 days) PAR levels in respect of crop duration.

The shortest time to flower was recorded under full sunlight (30 days). Compare to full sunlight, 25% PAR level (34 days) showed significant increase in time to flower. Plant grown under full sunlight took shortest period to reach the first

Table 13: Stem and leaf characteristics of yard long bean in the different light conditions

Light levels (% PAR)	Main stem length (m)	Inter-node length (cm)	Main stem Diameter (cm)	Leaves /plant	Leaf area (cm^2/leaf)	SLW (mg/cm^2)
100	4.19	13.75	1.23	399.8	99.3c	2.53
75	4.55	16.52	1.16	402.2	123.4	2.34
50	5.29	16.95	0.93	303.8	199.8	1.85
25	5.00	22.68	0.80	219.7	279.9	1.74
LSD (0.05)	0.59	3.45	0.16	97.32	26.27	0.21
CV (%)	8.36	9.49	7.63	14.70	7.49	7.40

flowering stage. It means that shading somewhat delayed flowering. Similar finding was reported by (Buge *et al.*, 1987). It is clear here that the reproductive period (first flower to maturity) was longer than vegetative period under shading condition. The fruit development period was significantly influenced by reduced PAR level (Figure 29). Fruit development period was the shortest (5.11 days) under full sunlight and the longest (7.04 days) under 25% PAR level. The longer duration of individual fruit under reduced sunlight, contributed to the longer crop duration by enhancing the post- anthesis growth duration. This is clearly visible at 25% PAR level compared to 100% PAR level.

Dry matter accumulation and partitioning

Different PAR levels significantly affected on the dry matter accumulation in leaf, stem and fruit (Figure 30). At 75% PAR level, the maximum stem dry matter (96.69 g/plant) was harvested which was followed by full sunlight (95.70 g/plant). Stem dry matter did not show any significant variation with the reduction in light levels up to 50% PAR. At 25% PAR the stem dry matter reduction was significant. Leaf dry matter gradually decreased with reduced PAR levels but the decrease was not significant at 75% PAR. The highest leaf dry matter of 108.2 g/plant was produced under full sunlight. The lowest leaf dry matter (74.77 g/plant) was produced by 25% PAR level. The maximum fruit dry matter (291.3 g/plant) was recorded under 75% PAR which was at par with that of 100% PAR level (257.1). The significantly lowest fruit dry weight (117.1 g/plant) was obtained from 25% PAR level. Under 75% PAR level, stem and leaf dry matter did not decrease

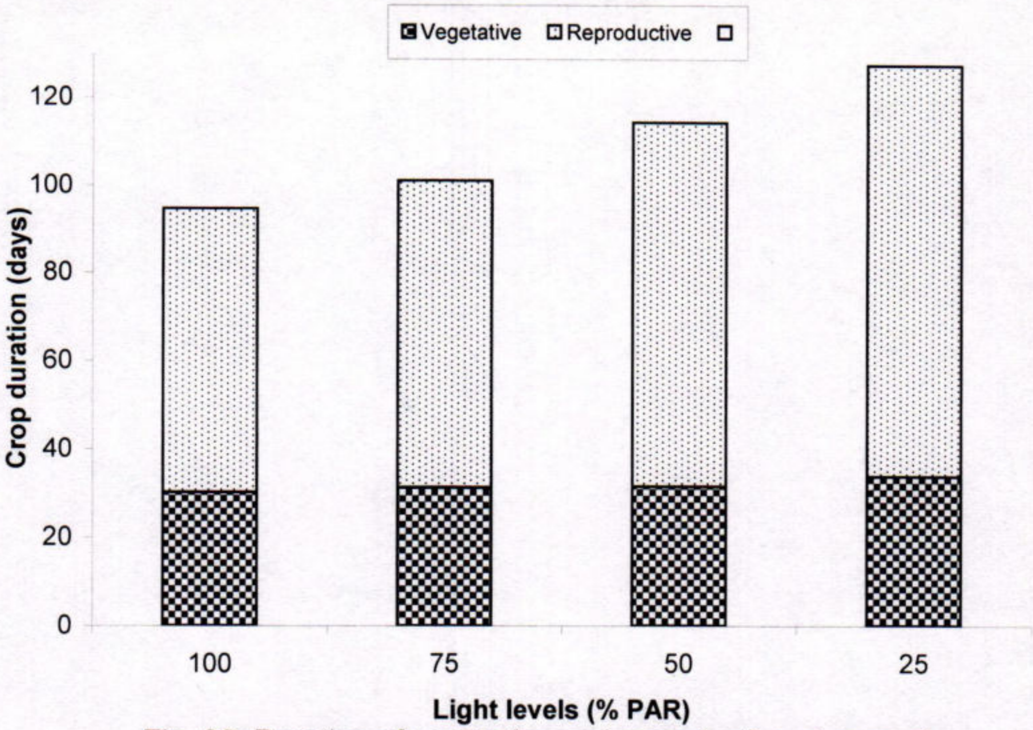

Fig. 28: Duration of vegetative and reproductive phases of yard long bean as influenced by different light levels .

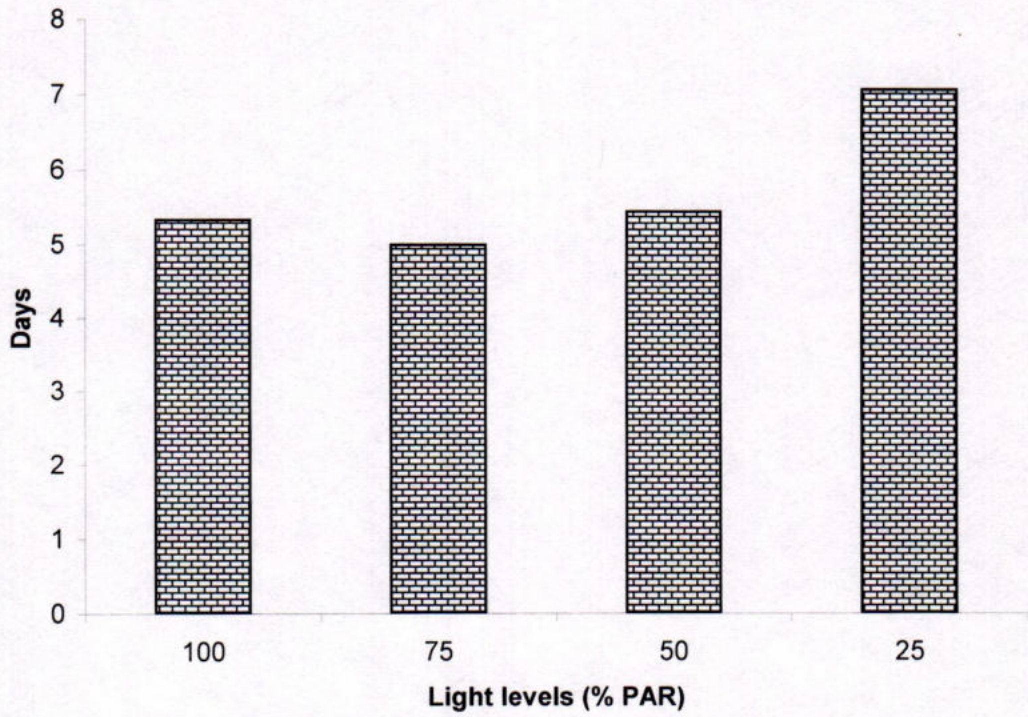

Fig.29: Fruit development period (anthesis to harvest maturity) of yard long bean as influenced by different light levels.

significantly compared to that of full sunlight Total dry matter (TDM) production in long yard bean plant was significantly affected by varying PAR levels (Figure 31). The highest amount of TDM (486.5 g/plant) was obtained under 75% PAR levels which was statistically similar to that of full sun light (461.0 g/plant). PAR levels below 75% light produced relatively small amount of TDM. The TDM recorded under at 25% PAR level (251.9 g/plant) was the lowest. The result also suggested that mild shading stress (i.e. at 75% PAR) did not show any adverse effect on the total dry matter accumulation in long yard bean but with increasing the shading stress total dry matter production decreases significantly. The LWR was lowest at 100%, which then increased at 25% PAR level (0.30)(Figure 31). There is no significant variation among 75% (0.24) full sunlight (0.24) and 50% (0.47) PAR levels. Reduction of PAR levels from 100% to 50% did not affect the percentage distribution of total dry matter to leaf. But at 25% PAR level considerable dry matter was utilized to foliage tissues. The higher relative total dry matter production under 75% PAR level (1.05) compared to any other PAR levels (Figure 32) indicates that yard long bean plants have got some advantage at 75% PAR in dry matter yield. Under 25% light yard long bean plant showed considerable reduction in total dry matter compared to full sunlight which in turn was attributed to poor leaf, stem and fruit dry weight. But high LWR at 25% light suggests that leaf dry weight was less adversely affected relative to other components. Actually yard long bean showed a tendency to maintain higher leaf area under low light stress for keeping total photosynthesis constant.

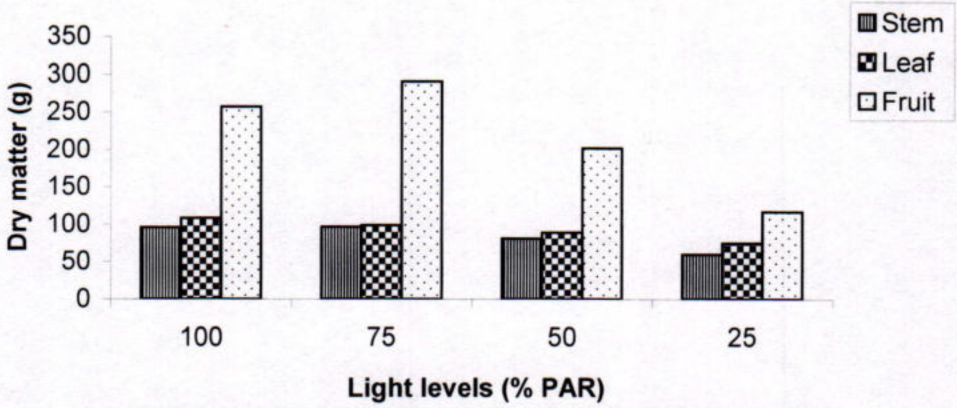

Fig.27: Distribution of dry matter jn the different above ground parts of yard long bean in different light levels

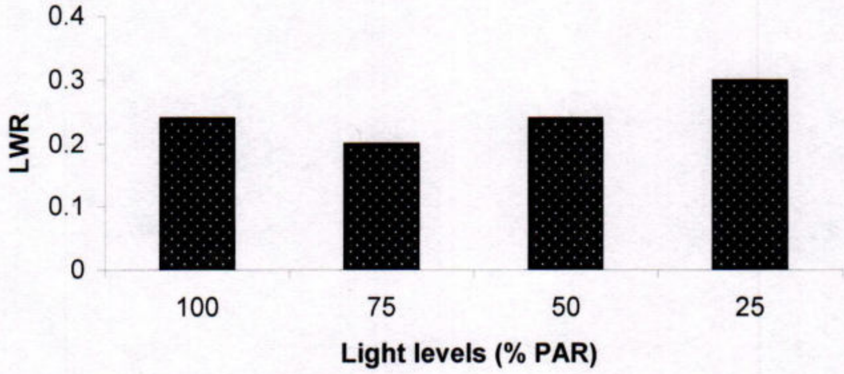

Fig 31: Leaf weight ratio of yard long bean as influenced by different light levels.

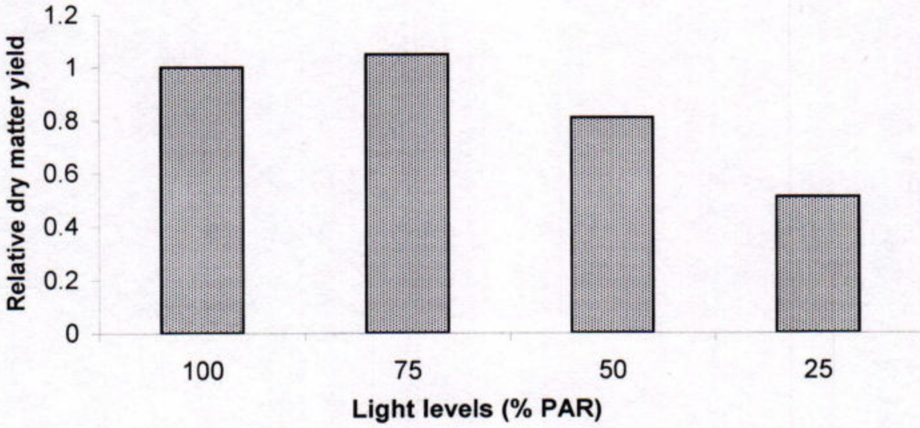

Fig. 32: Relative dry matter yield of yard long bean as influenced by different reduced light levels

Leaf pigment

The pigment content viz. chlorophyll a, chlorophyll b, chlorophyll a/b ratio and β- carotene differed under different PAR levels (Table 14). The lowest chlorophyll a content was recorded under 75% PAR level (8.85 mg/g) which was statistically similar to full sunlight (8.87 mg/g) but different from rest of the two treatments. The chlorophyll a content gradually increased with the reduction of PAR level. The highest quantity of chlorophyll a in leaf was obtained from 25% light (14.05 mg/g). Chlorophyll b also showed similar increasing pattern with the decreasing PAR levels. Significantly the highest amount of chlorophyll b was observed under 25% PAR levels (7.61 mg/g) while the lowest chlorophyll b content was under full sunlight (3.67 mg/g). The ratio of chlorophyll a/b gradually decreased with the decrease of PAR levels. The ratio of chlorophyll a/b was maximum in full sun light (2.42) as well as 75% light (2.32). Chlorophyll a/b ratio was significantly lower under 50% PAR level (2.10). Which further lowered to 1.84 under 25% PAR levels. Lower ratio of chlorophyll a/b under reduced sunlight of 50% or below compared to 100% sunlight suggested the extent of increase in chlorophyll b was higher than that of chlorophyll a . Under reduced light chlorophyll b is considered to be a major light harvesting pigment in the chloroplasts (Helton, 1983). So, less magnitude of reduction in chlorophyll b could be desirable adjustment to maintain the photosynthetic process under light limiting condition.

Total chlorophyll (a+b) content also maintained by a pattern of increasing value similar to chlorophyll a under reduced light condition. The highest amount of total chlorophyll was produced under 25% PAR levels (21.61 mg/g). Then it gradually decreased with the increase in PAR level up to full sunlight. The lowest amount of total chlorophyll was observed under full sunlight. The lower light intensity due to shading caused an increase in synthesis and accumulation of chlorophyll (Chen *et al.*, 1994). A linear relationship between PAR levels and leaf chlorophyll content of yard long bean was found to be highly significant (R^2= 0.8191**) (Figure 33.). The variation in the leaf chlorophyll content of yard long bean with the variation of light is well explained by the relationship.

Plant grown under reduced light condition had significantly lowered the amount of β-carotene in then leaves. The highest amount of β-carotene in leaf was recorded under 75% PAR level (4.07 mg/g). But there were no statistical difference among full sunlight (4.04 mg/g), 75% and 50% (3.45 mg/g) PAR levels in respect of β-carotene content. The significantly lowest amount of β-carotene was found in 25% PAR levels. The result was in agreement with that of Adams and Adams (1992) as they also found a reduction of β-carotene under shaded condition in yard long bean although α-carotene content was increased.

Nitrogen content

Reduced PAR level (at 25% PAR) showed significant influence on stem leaf and fruit nitrogen content (Table 15). The height stem nitrogen content (2.73 g/100

Table 14: Chlorophyll and β-carotene content (mg/g) in the leaf of yard long bean at different light levels

Light levels (% PAR)	Chlorophyll a	Chlorophyll b	Chlorophyll a/b	β-carotene
100	8.87	3.67	2.42	4.04
75	8.85	3.79	2.32	4.07
50	14.01	6.67	2.10	3.45
25	14.05	7.61	1.84	1.56
LSD (0.05)	1.30	0.84	0.24	0.67
CV (%)	5.70	7.73	5.31	10.28

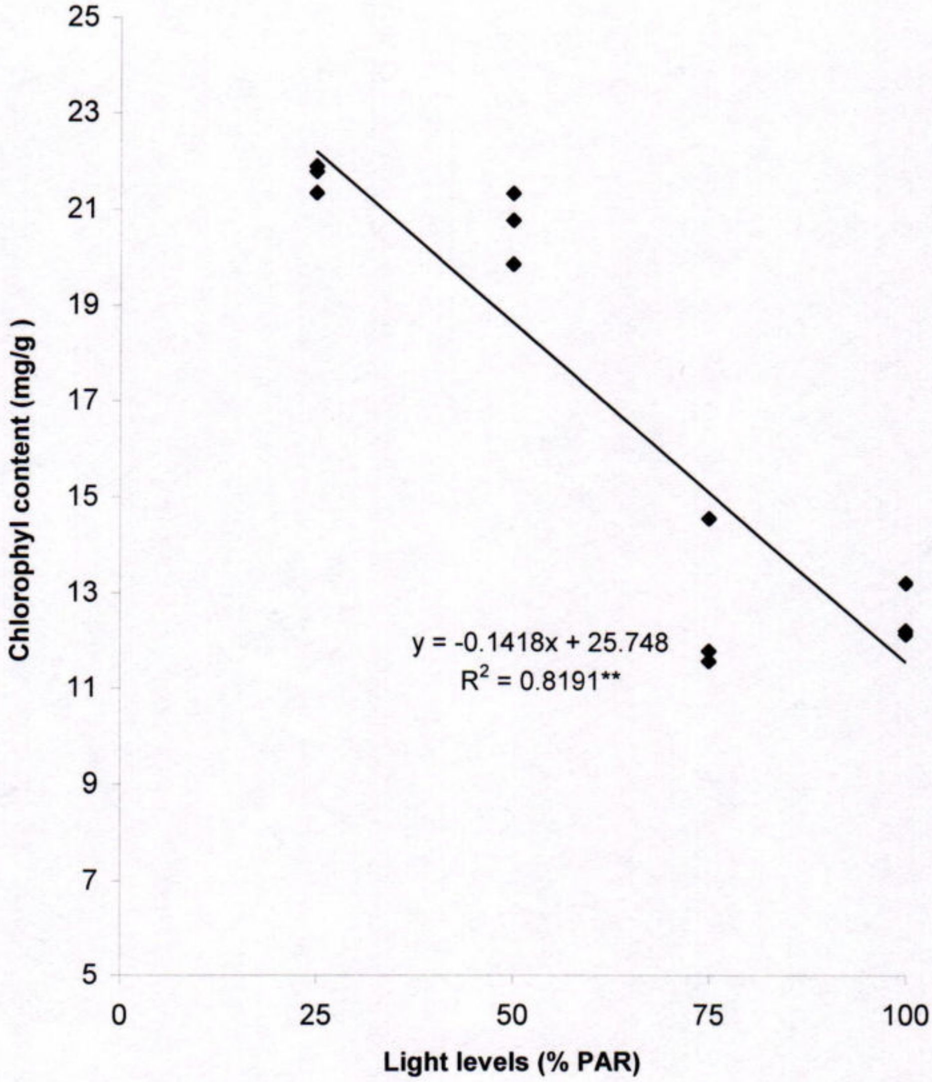

Fig.33: Relationship between different light levels and chlorophyll content in yard long bean leaf

g) was recorded under 75% PAR level. But there was no significant variation among full sunlight (2.6 g/100g) 50% (2.53 g/100g) and 25% (2.26 g/100g). The amount of leaf nitrogen was the lowest under full sunlight (3.27 g/100 g) and it then increased slightly under 75% PAR levels (3.34 g/100 g) but the difference was not significant. The highest amount of leaf nitrogen was recorded from 25% light treatments (3.71 g/100 g) which was statistically similar to that of 50% PAR levels (3.51 g/100 g) but significantly higher compared to leaf nitrogen content under any other higher levels of light in this experiment.

There existed a linear relationship between leaf chlorophyll and leaf nitrogen content estimated as $y = 0.0471x+2.7227$ ($R =.674^{*}$) where the R^2 value is significant (Figure 34). This positive linear relationship indicates that leaf nitrogen content increases with the increase of leaf chlorophyll content in yard long bean. Under reduced light conditions the yard long bean leaves were appeared to be deep green in colour compared to full sunlight. The increased chlorophyll content under reduced sunlight induced deep green colour to the leaf which, in turn, resulted in higher foliar nitrogen content. The highest amount of fruit nitrogen (4.66 g/100 g) recorded in 100% PAR level was statistically similar to that of 75% (4.52 g/100 g.) PAR level. The lowest fruit nitrogen content (3.63 g/100g) was observed from 25% PAR level. This result suggested that plants maintained higher leaf nitrogen under shade condition in expense of stem and fruit nitrogen.

Table 15: Nitrogen content in the above ground parts of yard long bean at different light levels

Light levels (% PAR)	Nitrogen content (g/100g)		
	Stem	Leaf	Fruit
100	2.60	3.27	4.66
75	2.73	3.39	4.52
50	2.53	3.51	4.05
25	2.26	3.71	3.63
LSD (0.05)	0.37	0.43	0.35
CV (%)	6.88	6.27	3.76

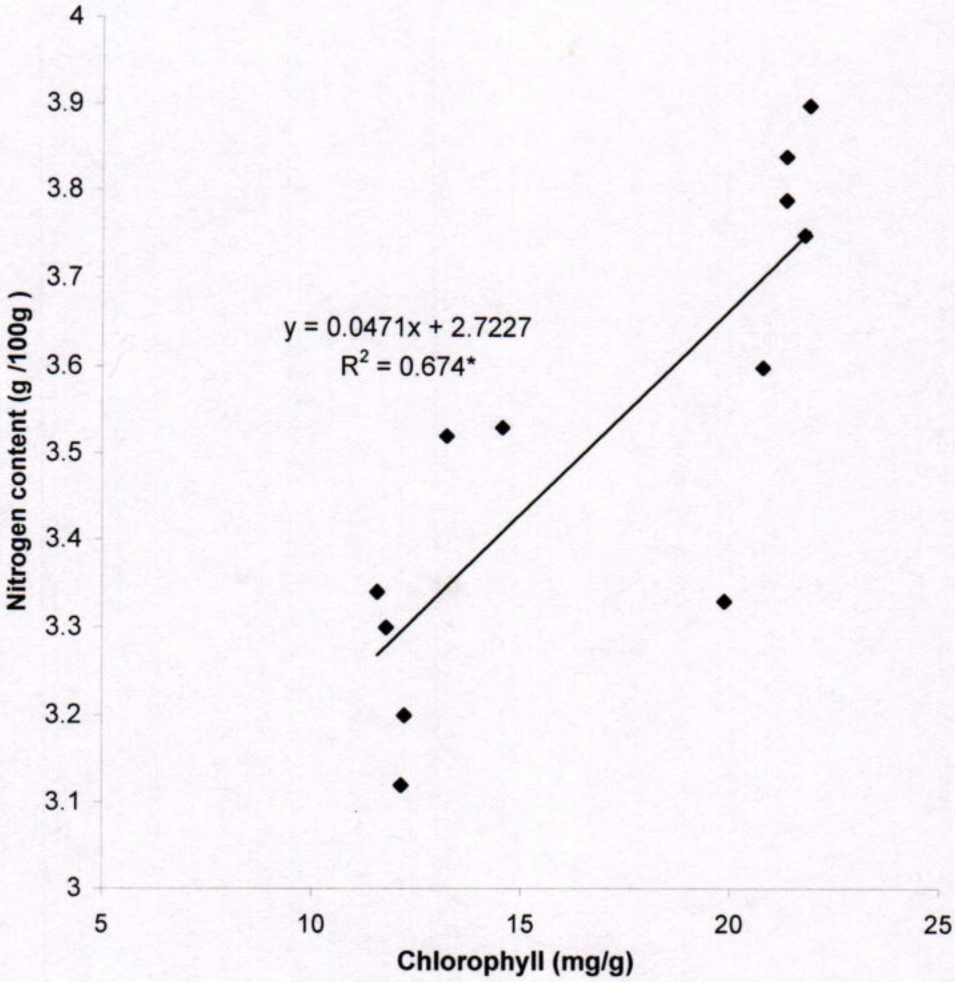

Fig.34: Relationship between chlorophyll and nitrogen content in leaf of yard long bean

Yield and yield components

Yield components were significantly influenced by different reduced PAR levels (Table 16). The maximum number of fruit was found under 75% PAR level (243.0 /plant) which was statistically similar to that of 100% (214.3 /plant) or 50% PAR level (212.0 /plant). A drastic reduction in the number of fruits per plant was recorded under 25% PAR (143/plant). Under reduced PAR levels similar influencing pattern in number of fruits was found in some varieties of mungbean (Miah, 2001). These results indicated that yard long bean can be grown even under 50% PAR level without significant reduction in number of fruit per plants as compare to the full sunlight. Reduction of PAR levels up to 75% induced non-significant variation in fruit length. Significant reduction of length observed when PAR level was reduced to 50%. The lowest fruit length was observed 25% PAR levels (44.99 cm). Fruit diameter was not significantly affected by reduced PAR levels. Individual fruit weight was significantly affected at different PAR levels. The heaviest individual fruit was recorded under 75% PAR level (15.41 g) and was statistically similar to those under 100% (14.74 g) and 50% PAR. However, it reduced markedly when the light availability was further reduced to 25% PAR level (12.51g).

There was significant influence on the yield of yard long bean under different PAR levels. Among the PAR levels, the highest yield per plant was recorded under 75% PAR level (3.51 kg) which was at par with that of full sunlight (3.31 kg) and 50% PAR level (2.79 kg). The lowest yield per plant was found under 25% PAR level (1.67 kg). Almost similar result was found by Aidy (1984) in tomato. The lowest yield per hectare was obtained from 25% PAR level (5.57t) compared to that of higher PAR levels. But the yield per hectare did not differ significantly among the treatments involving 100% to 50% PAR levels. The yield reduction at 25% PAR was contributed by the significant reduction of fruits per plant and individual fruit weight. The relative fruit yield of 1.08 under 75% PAR and 0.84 under 50% PAR revealed that only 75% PAR level seems to be favourable in yard long bean production compare to that of full sunlight (Figure 35). But yard long bean plant gave only 51% yield of full sunlight treatment under 25% PAR levels. It means that shading with 25% light exerted an adverse effect on the yield of yard long bean.

A quadratic relationship was found between fruit yield of yard long bean and light which is represented as $y = -0.0019x^2 + 0.3076x - 1.0792$ (R^2=0.864**). This findings indicated that majority of total variation in the yield of yard long bean can be explained by the above quadratic regression equation (Figure 36). This equation also stated that fruit yield of yard long bean was maximum i.e. 12.09 at 81.26% PAR level and beyond this PAR level (81.26%) fruit yield decreased at the rate of 0.0019 t/ha.

Table 16: Effect of different light levels on yield and yield components of yard long bean

Light levels (% PAR)	Fruit numbers/plant	Fruit length (cm)	Fruit diameter (mm)	Individual fruit weight (g)	Fruit yield/ plant (kg)	Fruit yield (t/ha)
100	214.3	54.86	4.30	14.74	3.31	11.01
75	243.0	54.48	4.37	15.41	3.57	11.89
50	212.0	48.65	4.46	13.39	2.79	9.28
25	143.0	44.99	4.77	12.51	1.67	5.57
LSD(0.05)	38.79	0.52	Ns	2.00	0.71	2.37
CV (%)	9.67	4.51	11.79	7.17	12.59	12.55

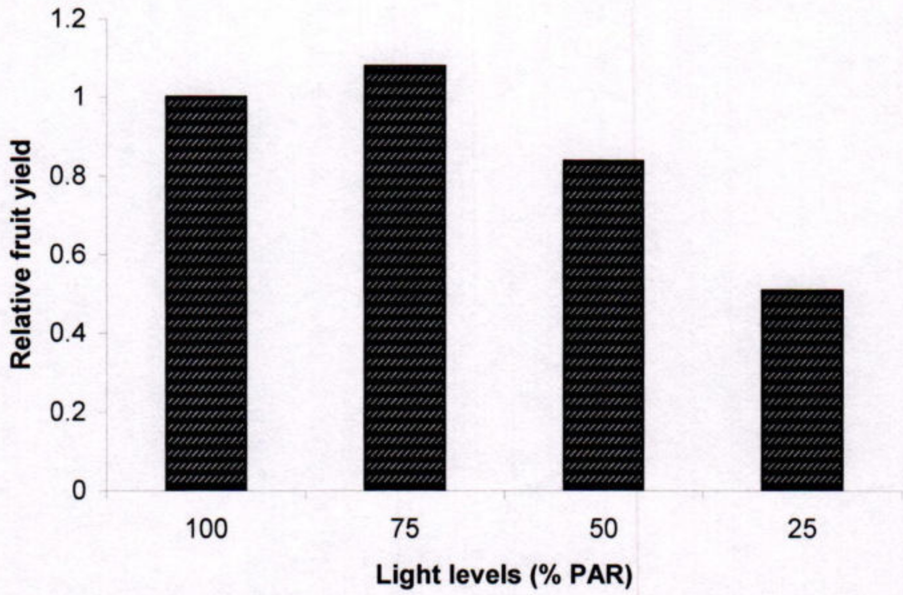

Fig.35: Relative fruit yield of yard long bean as influenced by defferent light levels

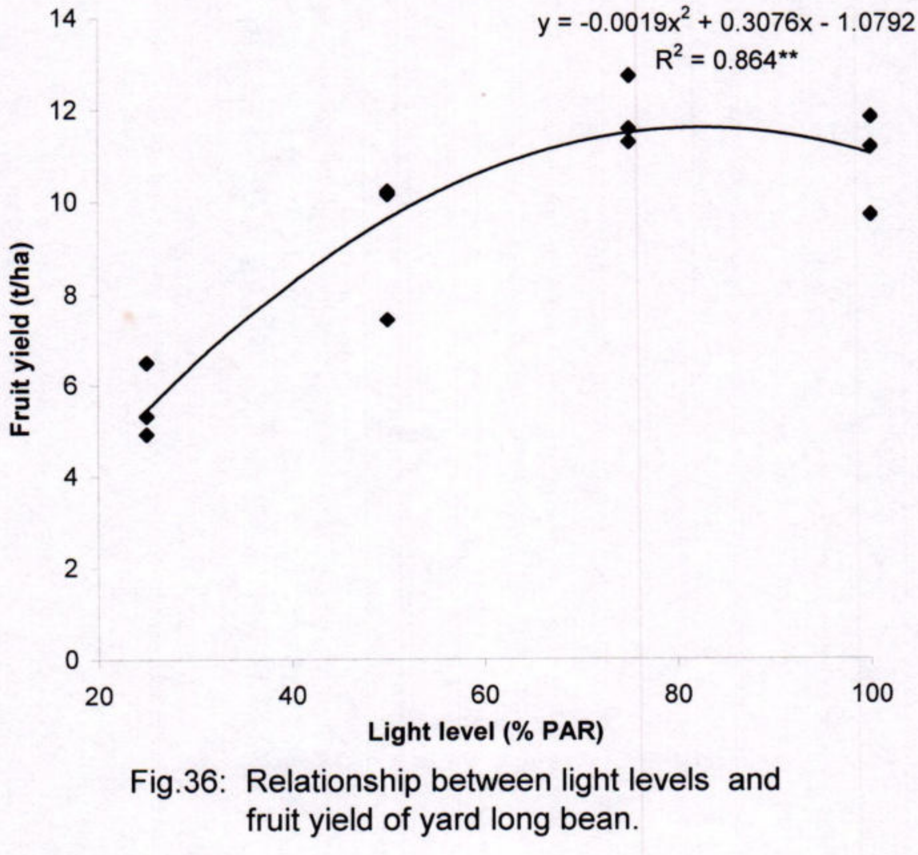

Fig.36: Relationship between light levels and fruit yield of yard long bean.

The overall results indicate that compare to full sunlight leaf number per plant, LWR and leaf dry matter did not reduce significantly with the reduction of light up to 50%. In addition the fruit development period and crop duration became longer at 50% PAR compare to full sunlight. Because of the combined of all these factors, plant gave higher number of fruit per plant and bigger individual fruit between full sunlight to 50% PAR Consequently yard long bean did not show significant difference in fruit yield between 100% to 50% PAR.

CHAPTER V

SUMMARY

Four experiments were carried out with four selected viny vegetables to investigate the morpho-physiological changes and yield performance under four different light levels. Of the four vegetables (viz. cucumber, ash gourd, sponge gourd and yard long bean) each one was included in a separate experiment. The experiments were done at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, during April to November, 2000. The treatments of each experiment consisted of four different PAR levels (i.e. 100 %, 75 %, 50 % and 25 %). The treatments were distributed following a Randomized Complete Block Design and replicated three times. Results of the experiments on morphology, dry matter accumulation, pigment content, nitrogen content, yield parameters and yield have been summarised as follows:

a) Cucumber

Main stem length chlorophyll content and fruit number per plant were increased whereas β-carotene content was decreased at 75% PAR and below.

Chlorophyll a/b ratio started to decrease when light was lowered to 50% PAR because of the less increase of chlorophyll a relative to chlorophyll b. At 50% PAR level internode length, individual leaf area, fruit development period, leaf nitrogen were increased but main stem diameter and SLW were decreased significantly compared to full sunlight. Plant under 50% shade condition took more days to attain first flower and more days to reach maturity.

At 25% PAR level leaf number per plant, dry matter of stem, leaf and fruit were decreased significantly compared to full sunlight. Total dry matter and LWR also decreased markedly at 25% PAR. Compare to full sunlight reduction of PAR at 25% resulted in lower fruit number per plant, individual fruit weight and shorter fruit length. Hence fruit yield per plant was decreased at 25% PAR level.

The highest relative fruit yield was obtained at 75% PAR level (1.43) was followed by 50% PAR level (1.04) and then by 25% PAR (0.41). Under reduced light level shade tolerant parameters viz. leaf number per plant individual leaf area, chlorophyll content, total dry matter, LWR and crop duration exerted positive effect on fruit yield. Consequently fruit yield did not decreased up 50% reduction of PAR compare to full sunlight.

b) Ash gourd

Main stem length and individual leaf area and chlorophyll content increased but main stem diameter and β-carotene decreased markedly at 75% PAR and below.

At 50% PAR leaf per plant, fruit nitrogen, total dry matter, fruit dry matter, fruit number per plant, individual fruit weight and fruit yield per plant decreased considerably compare to full sunlight. LWR and leaf nitrogen increased markedly at 50% PAR and below. A reverse trend of nitrogen content was observed in stem and fruit at same PAR level. Time to first flower, fruit development duration delayed at 50% PAR level.

Internode length and crop duration showed significant increase at 25% PAR level. Reduction in PAR to 25% reduced the SLW, stem dry matter and leaf dry matter.

Ash gourd gave higher fruit yield from 100% to 75% PAR levels. The higher fruit number and bigger fruit size positively influenced the fruit yield at 100% and at 75% PAR level. The relative fruit yield were 0.83, 0.57 and 0.25 at 75%, 50% and 25% PAR levels respectively. At 75% PAR level, less shade sensitive parameters i.e. individual leaf area, fruit development duration, crop duration and SLW favoured the individual fruit size consequently yield did not significantly reduced.

c) Sponge gourd

Changes of PAR levels did not induce any marked increase in main stem length. At 75% and below, internode length increased whereas β-carotene, fruit number, individual fruit weight and fruit dry matter content decreased significantly compare to that of full sunlight.

Individual leaf area, chlorophyll content, LWR, days to first flower, leaf nitrogen and crop duration were increased but main stem diameter, leaves per plant and SLW fruit length and total dry matter decreased significantly at 50% PAR and below. At 50% PAR, crop duration increases at reduced light level due to increase in days to first flower.

Fruit nitrogen content decreased and fruit maturity duration increased only at 25% PAR level. Higher fruit yield was obtained at full sunlight compare to any reduced PAR levels. At reduced PAR level, fruit yield reduced due to reduction of fruit number. The relative fruit yield at 75%, 50% and 25% PAR were 0.75, 0.18 and 0.06 respectively.

d) Yard long bean

At 75% PAR and below, main stem length increased markedly compare to full sunlight. At 50% PAR internode length, individual leaf area, leaf chlorophyll content and crop duration increased, whereas chlorophyll a/b ratio, leaf dry matter, fruit dry matter, total dry matter, main stem diameter, SLW, fruit nitrogen, fruit length, individual fruit weight were decreased considerably.

Reduction of PAR from 100% to 25% there was significant decrease in β-carotene, stem dry matter, number of leaves per plant and number of fruits per plant. At 25% PAR LWR, leaf nitrogen, days to first flowering and fruit maturity days increased significantly. The maximum fruit yield was harvested at 75% PAR as well as at100 % PAR. The higher fruit yield was contributed by higher fruit number and bigger fruit size. The relative fruit yields at 75%, 50% and 25% PAR were 1.08, 0.84 and 0.57 respectively. Less shade sensitive characters viz. LWR, leaves per plant, individual leaf area, days to first flowering and fruit development period favoured the fruit yield up to 50% PAR levels.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

Based on the extent of changes in morphology, leaf pigment content, nitrogen content, dry matter accumulation, yield components and yield in response to different light levels, the four vegetables viz. Cucumber, yard long bean, ash gourd and sponge gourd were found to be different. Compared to full sunlight, significant adverse effect did not appear in cucumber and yard long bean until the light was reduced to 25% PAR level. Significant adverse effect was visible only when the light was reduced to 50% PAR in ash gourd and in sponge gourd at 75% PAR.

Therefore, during summer season, cucumber and yard long bean are suitable for growing as understorey crop if only about half of the natural light is available. Ash gourd may be grown under 75% of natural light. But sponge gourd is suitable for uninterrupted light conditions. However, further experiments are needed with large number of genotypes of each crop to explain the physiological basis of shade tolerant mechanism.

CHAPTER VII

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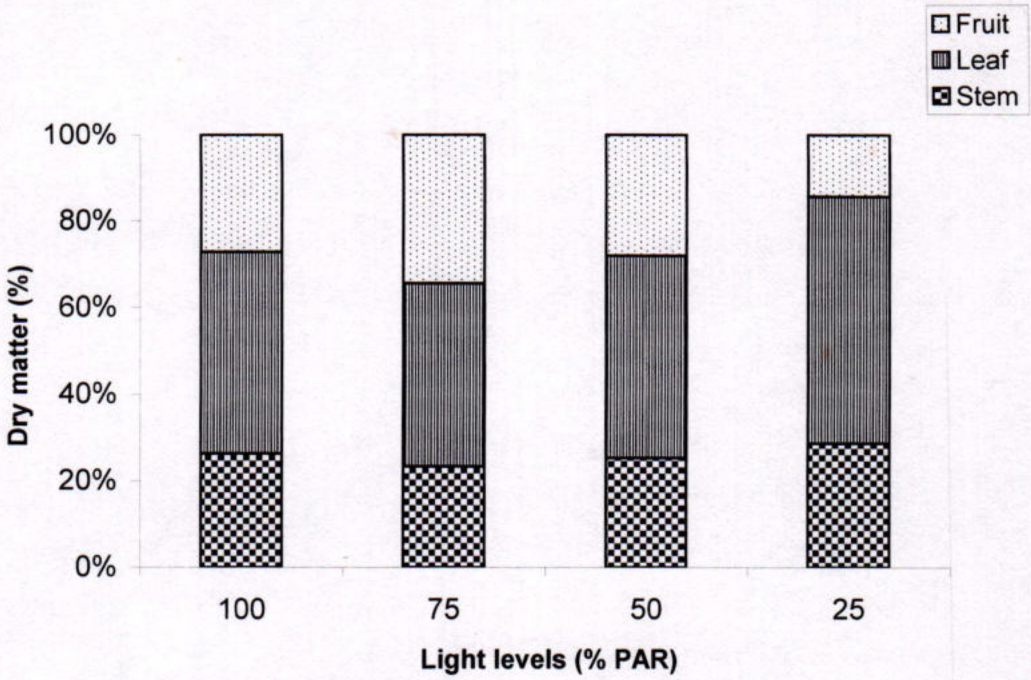
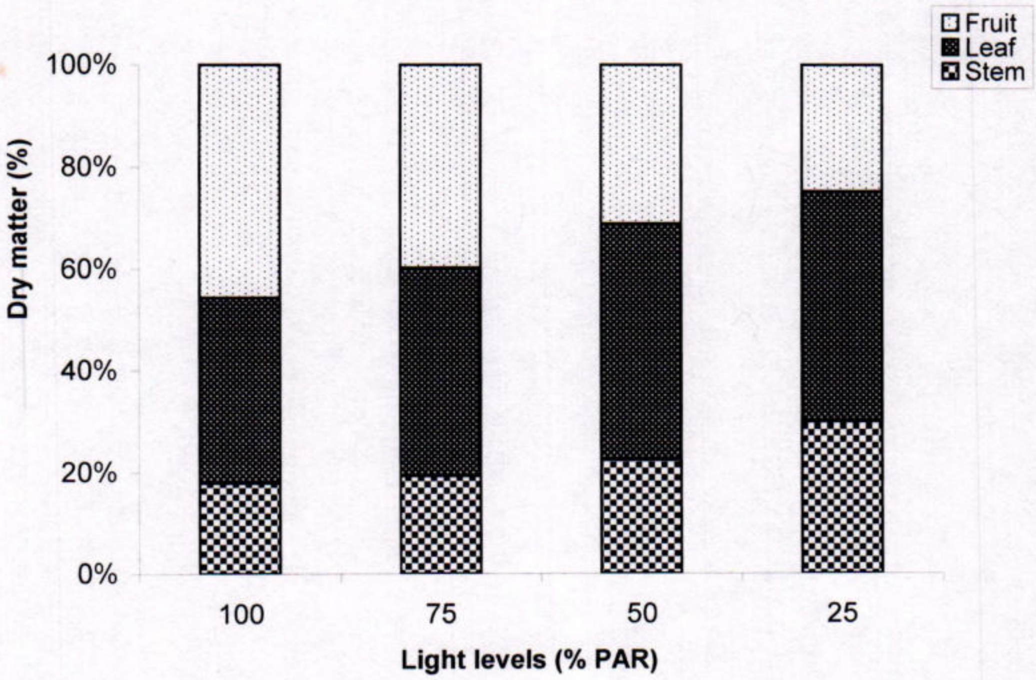
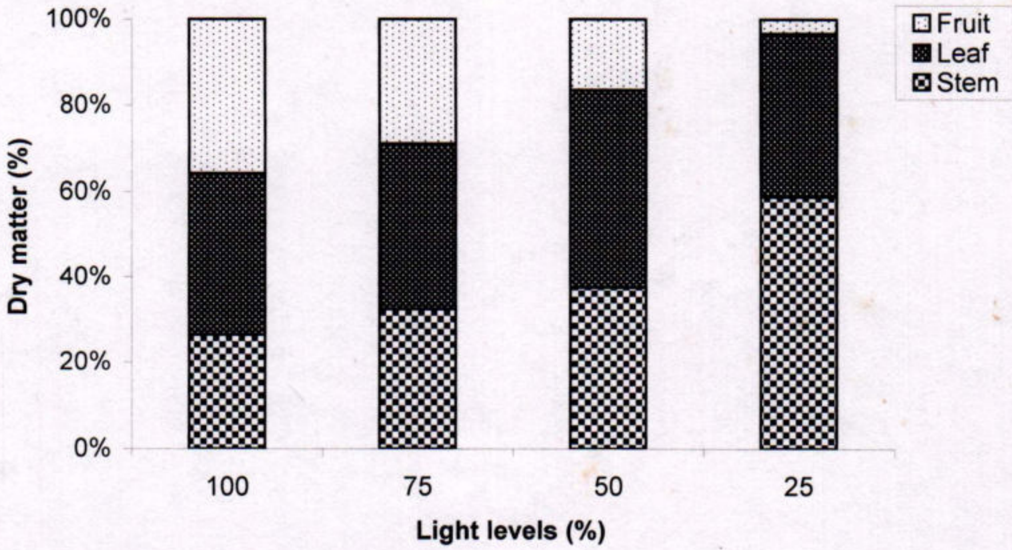


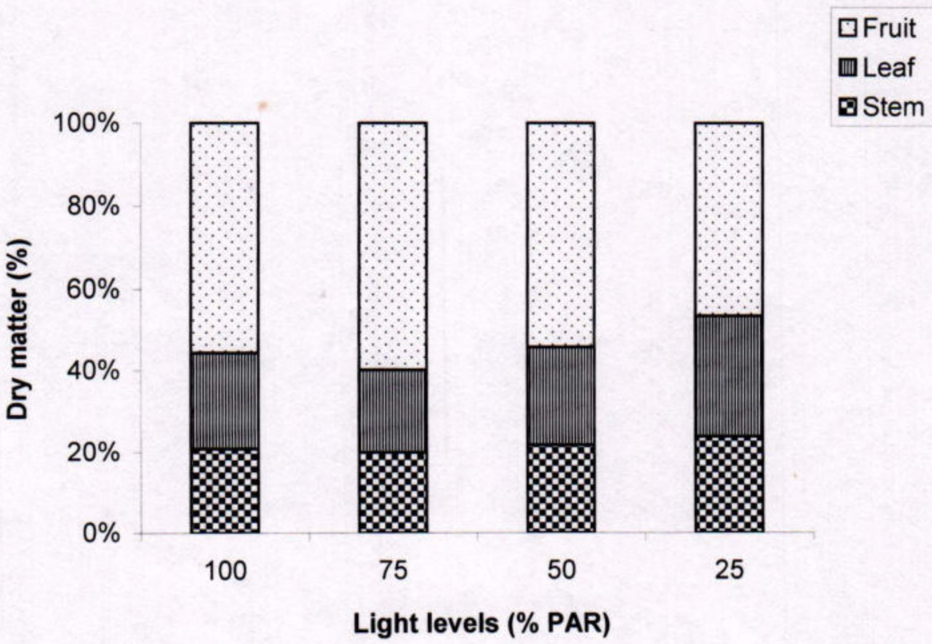
Appx.1: Distribution of dry matter in different above ground parts of cucumber in different light levels



Appx. 2: Distribution of dry matter in different above ground part of ash gourd in different light levels



Appx.3: Distribution of dry matter in different above ground parts of sponge gourd in different light levels



Appx.4: Distribution of dry matter jn the different above ground parts ofyard long bean in different light livels

Appendix 5: Maximum and minimum weekly temperature (^oC), relative humidity and rainfall during April , 2000 to November, 2000 at the farm of BSMRAU.

Week	Air temperature ^oC		Relative humidity		Rainfall (mm)
	Max.	Min.	Max.	Min.	
18 April – 24 April	32.9	21.9	92.7	49.3	89.05
25 April – 01 May	30.2	22.7	93.0	65.5	100.07
02 May – 08 May	29.5	21.2	93.7	61.0	67.01
09 May – 15 May	34.9	27.3	91.0	49.1	0.00
16 May – 22 May	33.9	25.5	92.1	61.0	74.33
23 May – 29 May	31.2	25.2	90.8	64.3	115.10
30 May – 5 June	33.1	24.8	90.9	66.9	36.58
06 June – 12 June	34.0	24.6	91.7	60.3	98.40
13 June – 19 June	33.6	25.2	91.8	59.9	35.96
20 June – 26 June	33.0	25.3	92.1	61.9	97.88
27 June – 3 July	34.2	28.1	91.8	67.1	5.22
04 July – 10 July	34.9	28.5	89.1	66.2	80.01
11 July – 17 July	34.7	28.0	89.6	68.9	82.09
18 July – 24 July	32.4	25.8	92.3	68.4	87.74
25 July – 31 July	32.7	27.1	92.5	66.4	0.00
01 Aug. – 07 Aug.	33.1	27.5	92.9	67.3	9.81
08 Aug. – 14 Aug.	31.9	25.8	92.3	66.7	104.19
15 Aug. – 21 Aug.	32.4	26.9	93.3	71.1	46.21
22 Aug. – 28 Aug.	35.0	28.7	93.1	69.6	51.56
29 Aug. – 04 Sept.	33.1	26.5	93.5	69.6	51.67
05 Sept.– 11 Sept.	33.2	27.5	92.8	67.2	9.52
12 Sept.– 18 Sept.	32.5	28.4	92.2	68.2	25.79
19 Sept.– 25 Sept.	31.3	26.1	92.8	68.3	118.86
26 Sept.– 02 Oct.	33.1	27.8	92.8	69.6	22.27
03 Oct. – 09 Oct.	32.5	27.2	93.1	67.4	26.62
10 Oct. – 16 Oct.	33.0	26.2	94.1	61.7	38.48
17 Oct. – 23 Oct.	33.5	26.0	95.2	55.2	18.42
24 Oct. – 30 Oct.	29.5	25.1	95.2	51.9	206.69
31 Oct. – 06 Nov.	32.2	24.5	95.8	57.9	0.00
07 Nov. – 13 Nov.	30.1	22.4	94.8	62.3	0.00
14 Nov. – 20 Nov.	28.8	22.2	95.7	64.6	0.00