PERFORMANCE OF FIVE WINTER VEGETABLES UNDER DIFFERENT LIGHT CONDITIONS FOR AGROFORESTRY SYSTEMS

MD. MAIN UDDIN MIAH

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MD. MAIN UDDIN MIAH

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Certificate of Approval

(Dr. Md. Giashuddin Miah)
Major Professor and Chairman
Advisory Committee

(Dr. M. Mofazzal Hossain)
Member
Advisory Committee

(Dr. M. Mustaque Ahmed)
Member
Advisory Committee

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ALLAH-SUBHANA-TA-UALA

THESIS ABSTRACT

PERFORMANCE OF FIVE WINTER VEGETABLES UNDER DIFFERENT LIGHT CONDITIONS FOR AGROFORESTRY SYSTEMS

BY

MD. MAIN UDDIN MIAH

The performance of five winter vegetables was evaluated under four different light levels i.e., 100, 75, 50 and 25 percent Photosynthetically Active Radiation (PAR) at the experimental farm of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur during November 1999 to March 2000. Different light levels i.e., 75, 50 and 25 percent PAR were attained by using nets of different pore sizes. Four winter vegetables i.e., cabbage, carrot, radish and tomato were grown as in individual experiments following the RCBD design and three varieties of eggplant i.e., Nayantara, Kajla and Uttara were grown separately in Split Plot Design.

Plant height of all the five vegetables increased gradually with the decreased of light level and significantly the longest plant was found under 25 percent PAR level i.e. severe shade level. Other parameters of the tested vegetables varied differentially due to variation of light levels.

In cabbage, outer leaf length increased gradually with the decreased of light levels. Outer leaf breadth and yield contributing characteristics of cabbage i.e. head length, head breadth and head fresh weight were increased progressively up to 50 percent reduction of light levels. Further reduction of light level, the above

parameters were drastically decreased. Fresh and dry yield (ton/ha) of cabbage produced under 50 percent PAR level were numerically higher (29.98 and 1.90, respectively) than those of yields obtained under full sunlight (28.92 and 1.72, respectively) and 75 percent PAR (29.52 and 1.89, respectively).

In carrot, two parameters, i.e. plant height and leaf length were increased with the decreased of light levels. But the other parameters showed the superior performances under 25 percent reduced light level (75% PAR) and the least performances under 25 percent PAR level. The highest yield (30.64 ton/ha) was found under 75 percent PAR (25% reduced light) which was even statistically higher than those of the yields obtained under full sunlight (100% PAR) and 50 percent PAR.

In radish, leaf length and leaf breadth increased gradually with the decreased of light level. In case of number of leaves per plant and dry weight of leaves per plant, the best performances were observed under 75 percent PAR level (25% shade level) and the poorest performances were observed under 25 percent PAR level (75% shade level). The values of the yield contributing characteristics such as radish length and radish girth were found the highest under 75 percent PAR level. Similarly, significantly the highest fresh yield of radish was found under 75 percent PAR level.

In tomato, some parameters such as number of primary branches, number of fruit per cluster, fruit diameter, fruit weight were decreased with the decreased of light levels, and other parameters such as number of leaves per plant, number of cluster per plant, number of fruit per plant and yield were increased up to 25 percent reduction of PAR level. Further reduction of PAR level, these parameters were decreased gradually. The total yield of tomato obtained under full sunlight (94.62 ton/ha), 25 percent reduced light (96.02 ton/ha) and 50 percent reduced light (87.70 ton/ha) did not vary significantly but yield obtained under 75 percent reduced light level decreased remarkably.

Among three varieties of eggplant, primary branches of Nayantara and number of leaves per plant of all the varieties were the highest under 75 percent PAR level. Fruit length and number of fruits per plant of all the three varieties were higher under 100 percent PAR. Fruit diameter of Nayantara only and fruit weight of all the varieties were higher under 75 percent PAR level. Fruit diameter of other two varieties i.e. Kajla and Uttara were higher under 100 percent PAR. Yield (t/ha) of eggplant irrespective of varieties were the highest under 100 percent PAR. However, yields decreased gradually with decreased of light levels.

Relationship between light and yields of the studied vegetables were estimated. In case of eggplant, linear relationship between fresh yield and percent PAR was found, whereas in case of cabbage, carrot, radish and tomato quadratic (polynomial) relationships were found.

From the above studies, it may be stated that the performances of different winter vegetables under different light levels were different. But their degree of adaptability to the different light levels i.e., ability to grow under shade levels in agroforestry system may be ranked as cabbage>carrot> tomato>radish>eggplant (Kajla/Nayantara>Uttara).

BIOGRAPHICAL SKETCH

The author was born on October 15, 1969 in the village of Katara, Mirzapur, Tangail, Bangladesh, the first of five children of Md. Hakim Uddin Miah.

He completed his elementary education from Katara Primary School, Mirzapur, Tangail; secondary education from Jamurki N.S.A.G. High School, Mirzapr, Tangail in 1984 and higher secondary education from Tejgaon College, Farmgate, Dhaka in 1986. He got first division both in secondary and higher secondary school certificate examinations. He earned the degree of B. Sc. Ag. (Hons) with first class (20th position) in 1990 (held in 1993) from Bangladesh Agricultural Institute affiliated at the Bangladesh Agricultural University, Mymensingh, Bangladesh.

Having Bachelor's degree, he joined in B.A.F Shaheen College, Kurmitola, Dhaka on May 05, 1994 as a senior teacher (Agriculture) and served there up to November 25, 1997. After that, he joined at the Hajee Mohammad Danesh Agricultural College under the Bangladesh Agricultural Research Institute (BARI) on November 27, 1997 as a lecturer, Department of Agroforestry. The author was partially awarded a BARI funded scholarship for pursuing MS degree in Agroforestry and Environment at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. His major department was Agroforestry and Environment and minor were Horticulture, Agronomy and Soil Science.

The research venue was at the field laboratory of the Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, (BSMRAU).

He is happily married to Jahanara Akter and has been blessed by the Almighty Allah with two daughters Somyea Tangeem and Humayra Tasneem.

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Summer, 2001 **The Author**

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CHAPTER I

INTRODUCTION

Human nutrition is very essential in order to develop a nation in all respect. Vegetables may play a vital role in this aspect. In the recent years, the value of vegetables has been recognized as an important item of daily human diet all over the world. They have been playing a very important role in our daily diet by providing taste, palatability, variability and increase appetite. Generally vegetables are rich sources of minerals, vitamins and essential amino acids. They are essential for a balanced diet and neutralizing the acids produced during digestion of rich foods (meats cheese and fatty foods). They are considered as one of the most important groups of food crops having features of high nutritive value, labour-intensive, relatively higher yield and higher fiscal gain. They are considered as a cheap natural source of supplementary food and can be grown in a short duration. Being labour intensive, vegetable production creates opportunities for employment.

The average consumption of vegetables in Bangladesh is only 70 g per head per day including potato and sweet potato. Except tuber crops, it is only 30 g as against the FAO recommendation of 200 g. To supply the minimum daily requirement of 200 gm vegetables/head/day, national production of vegetables should be over 10 million tons. In addition, population of Bangladesh is increasing rapidly, therefore, demand for vegetables is increasing simultaneously. Whereas the areas under vegetable production including tuber crops are 3,27,000 ha that produce 2.76 million metric tons of vegetables yearly (BBS, 1998). Unfortunately these limited areas are decreasing due to increasing the housing and other facilities of the ever-increasing population as well as increasing the area of boro rice and wheat in winter season. Under these situations, new efforts/techniques must be developed to bridge the wide gap between supply and demand for vegetables.

Recently, some techniques have already been advocated to over come the future food challenges including vegetables, agroforestry is one of them. Agroforestry, the integration of tree and crop/vegetable on the same area of land is a promising production system for maximizing yield (Nair, 1990) and maintaining friendly environment. Growing of crops/vegetables in association with trees are becoming popular day by day for their higher productivity, versatile use and environmental consciousness among the peoples.

Among the different traditional agroforestry systems, homestead agroforestry is one of the oldest and potential systems because of its diversified role in household economy. There are about 15.4 million homesteads in the country which comprises about 0.3 million hectares of lands and most of the vegetables produced and consumed in the country are coming from these homesteads (Abedin and Quddus, 1990). These areas are also increasing due to construction of new houses for the ever increasing population. Traditionally farmers grow different types of trees and vegetables in association with trees in their homesteads, where productivity of vegetable is low due to lack of appropriate combinations. From time immemorial, a large number of diversified tree species are grown in the homesteads, and recently many exotic species are included. Therefore, to make the homestead agroforestry systems more productive and profitable, suitable tree species and vegetable crops that would be compatible to each other in terms of resource sharing particularly light should be identified.

Besides the homesteads and adjacent land, one-eighth of the land surface area of Bangladesh consists of hills and valleys, that also offer potentials for year round vegetable production under agroforestry system.

In Agroforestry systems, the basic growth resources viz., light, water and nutrient become the determinative factor for inevitable competition for the crop vegetables species grown in association trees, resulting mark depletion in the productivity of under-story crops/vegetables. Among different resource limitations, light availability is the most important one for the performance of the understorey crops/vegetables, particularly, where an upperstorey perennial forms a continuous overstorey canopy (Miah, 1995). Light is the only source that provides energy for photosynthesis which is the basis of vegetable production. Unlike water and nutrients, light can not be captured and stored for later use in the way that other natural resources are managed.

For identifying the compatible tree-vegetable combinations, particularly understorey species i.e., different vegetables should be screened out in terms of their adaptability and yield under different shade levels created by the upperstorey tree species. For this purpose, the best way of experimentation is to grow different vegetables under different tree species. But light transmission ability of a tree species not only depends on tree species but also several other factors such as age of the tree, growth pattern of the tree, etc. Hence it may not be wised to suggest the farmers to grow vegetables under trees directly before knowing the responses of a particular vegetable under different light levels. So, if we know the shade tolerance limits of different vegetables in terms of growth and yield, it would be very useful information for selecting the best tree-vegetable combination. Therefore, it would be wised to conduct experiments under artificial shade conditions for screening of different vegetables in terms of their growth and yield performance.

In Bangladesh, a large number of vegetables are grown of which most of them are grown in winter season. Financial returns from vegetables show that winter vegetable production especially is more profitable than the production of most field crops (BBS 1997). Among the different winter vegetables, cabbage, carrot, radish, tomato and eggplant are the important winter vegetables in Bangladesh. Cabbage is mostly employed as culinary and dietic article. Radish is important for its quick growing nature and high yield potential. It is easily cultivated as a companion crop or intercrop between the rows of other vegetables. Tomato is a well known and a very popular vegetable grown successfully throughout Bangladesh. Tomato is popular for its diversified use and its nutritional value. Eggplant is one of the most important fruit vegetable for its day nutral nature. It is considered as a commercial vegetable and is grown all over the Bangladesh. Though the aforementioned vegetables are very common to all and have good potential in our climate, none of them was systematically tested in agroforestry system or in artificial shade condition to see their production ability under partial shade condition.

In the view of proper utilization of homesteads, hilly areas or other shaded places and to increase the production of winter vegetables, the present study was undertaken with the broad objective to evaluate the performance of five winter vegetables under different reduced light levels for agroforestry systems. The specific objectives of the study were:

1. To characterize the morphological behavior of winter vegetables grown under different light levels.

2. To evaluate the yield and yield attributes of the selected winter vegetables grown under different light conditions for selecting suitable winter vegetables for agroforestry system.

3. To find out the relationship between light and yield of selected winter vegetables.

CHAPTER II

REVIEW OF LITERATURE

The review of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, reports, newspapers, periodicals and other form of publications are presented below:

Concepts of Agroforestry

Agroforestry is an age-old and ancient practice. It is an integral part of the traditional farming systems of Bangladesh. The concept of agroforestry probably originated from the realization that trees play an important role in protecting the long range interests of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture" (PCARRD, 1983). Agriculture and forestry were considered before as two distinct areas but these practices are now considered as complementary. This was brought about by the increasing realization that agroforestry can become an important component of ecological, social and economic development efforts.

Agroforestry is the idea of combining forestry and agriculture on the same piece of land. The basic concept of intercropping has been extended to agroforestry system. Many authors have defined agroforestry in different ways. A widely used definition given by the International Council for Research in Agroforestry (Nair, 1983) is that agroforestry is a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land management unit as agricultural crop or animal in some form of spatial arrangement or temporal sequence.

Vergara (1982) defined agroforestry as a " system of combining agricultural and tree crops of various longevity (ranging from annual through biennial and perennial plants), arranged either temporally (crop rotation) or spatially (inter cropping) to maximize and sustain agricultural production."

MacDicken and Vergara, (1990) stated that agroforestry in a means of managing or using land (i.e., a land use system) that combines trees or shrubs with agricultural/horticultural crops and/or livestock.

Saxena (1984) pointed out that agroforestry utilizes the inter spaces between tree rows for intercropping with agricultural crops and this does not impair the growth and development of the trees but enable farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

From a bio-economic point of view, Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmers or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis.

From a business point of view agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously on the same land area.

Ong (1988) reported that by incorporating trees with arable crops, biomass production per unit area could be increased substantially when the roots of trees exploit water and nutrients below the shallow roots of crops and when a mixed canopy intercepts more solar energy.

According to Solanki (1998), agroforestry can significantly contribute in increasing demand of fuel wood, fodder and lack of cash and infrastructure in many developing countries. He also stated that agroforestry has high potential to simultaneously satisfy 3 important objectives : (i) protecting and stabling the ecosystems; (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer etc.); (iii) providing stable employment, improved income and basic material to rural populations.

In traditional agroforestry systems of Bangladesh, farmers consider trees as saving and insurance against risk of crop failure or compensate low yields of crops (Akter *et al.*, 1989). Homestead gardens are common in Bangladesh where the farmers take up combination of 10-15 species of fruit, ornamental and multipurpose trees along with vegetables to meet their own or aesthetic value (Rang *et al.*, 1990).

Trees are grown in the crop land, homestead, orchard not only produce food, fruits, fodder, fuel wood or to generate cash for various purposes (Chowdhury and Satter, 1993) but also gives better living environment (Haque, 1996).

Importance of Light in Agroforestry

Agroforestry system that incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops (Miah, 1996).

The yield advantage of conventional intercropping has been explained in terms of improved capture or utilization of growth resources (Willey *et al.*, 1986). The resource capture by agroforestry systems will probably be greater than in sole crops (Ong *et al.*, 1991).

Limiting light (shade) is obviously the most important factor that causes poor performance of understorey crops. The key to the development of compatible tree-crop combination in agroforestry is greater light interception by understorey crops. In India, it is widely believed that shading by trees is responsible for poor yields of associated crops (Ong *et al.*, 1992).

One of the major constraints of microclimate and growth in agroforestry practice 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 crowns and spectral quality of sunlight under partial shade (Reifsnyder, 1987).

In a trials between December and March, the average fruit yields of tomatoes, cucumbers, phaseolus beans, capsicums, melons and okras grown under plastic tunnels were 12.4, 8.67, 2.0, 4.32, 1.89 and 2.9 kg/m^2, respectively, and for crops grown in the open the corresponding figures were 1.53, 0.47, 0.8, 1.12, nil (melons were not grown in the open) and 0.5 kg/m^2. (Aidy, 1984).

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).

Okigbo and Greenland (1976) and Okigbo (1980) identified more efficient use of light resources by plants of different heights and canopy structures as one of the advantages to be gained by growing crops in mixed stands.

The severity of competition in agroforestry system, ultimately crop yield is dependent upon the partitioning of resources, primarily of light and water between trees and crops (Howord *et al.*, 1995).

Essentially the underlying processes involved in the partitioning of resources (e.g. light water and nutrients) are not well understood. A better mechanistic understanding of resource capture and utilization in agroforestry system is required to facilitate the development of improved systems in terms of species combinations, planting arrangement and management (Howord *et al.*, 1995).

Characteristics of Tree Species in Agroforestry Systems

Selection of suitable tree species is vital in an agroforestry system. Nair (1980) considered the most choice of suitable plant species that can grown together as important factor in ensuring the sources of agroforestry. The most appropriate species for this system remains an open question for research. King (1979) listed the characteristics at tree species that should be grown with agricultural crops:

a) They should tolerate relatively high incidence of pruning.

b) They should have a low crown diameter to bole diameter ratio.

c) They should be light branching in their habit.

d) They should be tolerant of side shade.

e) Their phylotaxie should permit penetration of the light of the ground.

f) Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to the growth of the annual crop in conjunction with which their being raised.

g) The rate of litter fall and litter decomposition should have positive effect on the soil.

h) The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics which reduce competition for solar energy, nutrient and water.

i) Their root systems and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crops.

Rachie (1983) pointed out the following factors to be considered during the selection of woody legumes for intercropping with annuals in the low land tropics;

i) ease of establishment from seeds or seedlings.

ii) rapid growth and high productivity of foliage and wood.

iii) limited maximum size (may be optimum in small trees).

iv) good coppicing ability (regrowth following topping).

v) effective nutrient recycling abilities especially di-nitrogen fixation.

vi) multiple uses: food, feed, fire wood, construction materials and other products and services (shade, shelter etc.).

vii) minimal competition with shallowly rooted annual crops.

viii) small leaflets readily detached when dried and quickly decomposed when used as fertilizer.

ix) a high proportion of leaves to secondary branches.

x) good tolerance for drought, low fertility and others.

xi) freedom from pests and diseases and

xii) ease of control of eventual elimination.

Purohit (1984) suggested to select those species which would (i) not compete for moisture, space and air (ii) supply nitrogen in the soil (iii) provide food, fodder, fuel and timber (iv) maintain proper ecosystems (v) have no toxic effects to the crops; and (vi) have thin and erect leaves. Singh (1984) opined that suitable species should be multipurpose, well-adapted to different sites, easy to establish; have-nitrogen-fixing ability, rapid growth and ability to coppice.

Hegde and MacDicken (1990) pointed out some criteria for planting trees under the agroforestry system: (i) non-interference with arable crops, (ii) easy establishment, (iii) fast growth and short gestation period (iv) non-allelopathic effects on arable crops, (v) ability to fix atmospheric nitrogen, (vi) easy decomposition of litter, (vii) ability to withstand frequent lopping, (viii) multiple uses and high returns, and (ix) ability to generate employment.

However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local soil and environmental conditions.

Response of Crops in Agroforestry Systems

The response of different crops to the agroforestry systems was different. The performance of field crops in agroforestry systems is influenced by the tree and crop species and their compatibility, spacing between tree lines, management practices, soil and climatic factors.

It has been reported that shading reduced leaf number, leaf area and thickness of dry bean (Crookston *et al.*, 1975). They also reported 38 percent decrease in photosynthesis per unit area of shaded leaves.

Fifty percent shading during ear formation and milking stage of rice decrease yield by 48 percent and 18 percent, respectively (Park and Kwon, 1975).

Park *et al.* (1982) reported that shading reduced the light saturation rate, compensation point, net assimilation rate, leaf number, length and plant dry weight at harvest of spinach, lettuce and chinese cabbage, particularly with 86% shading + fog mist. They also reported that the highest yields of these vegetables were obtained with 42% shading + fog mist.

Nayak and Murty (1980) reported that yield reduction of rice by 47, 57 and 74 percent in 75, 50 and 25 percent of normal light, respectively. This was mostly due to impaired dry matter production, panicle number and grains per panicle.

Akber *et al.* (1990) reported that wheat yield under different tree species (E. camaldulensis , Mulberry, Siris, Ipil-ipil) did not show any significant difference as compared to control yield.

Yamoah *et al*. (1986) reported that maize height, stover and cob weights were reduced (though insignificantly) in maize rows close to the shrub hedgerows compared with those in the middle of the alley.

Growth of trees and seasonal yields of understudy crops were measured by Hicking *et al.* (1998) over a five year period for 4 crops grown under 17 tree species at 8 X 8 m spacing in wetland rice field. All tree species grew well in rice fields, at rates comparable to their growth in forest plantations. Top and root pruning reduced average tree girths by up to 19% and average tree volume by up to 41% depending on intensity of pruning. The crops monitored were *Oryza sativa*, *Triticum aestivum, Corchorus oletorius, and Lens culinaris*. Crop yields under the trees averaged 93% of the corresponding yield outside the tree canopy.

Jadhav (1987) reported that partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73 percent because of reduction in number of panicles per plant (51.5%), number of grain per panicle (16.7%) and increase in number of unfilled spikelets (42.1%) in 25 rice cultivars.

Chaturvedi and Ingram (1989) mentioned that pre-flowering shade (50% shade) resulted in reduced leaf area, tiller number, spiklets per panicle, whereas post-flowering shade reduced filled spikelet fraction and grain weight in rice.

Rabarimandimby (1992) observed that hedgerows significantly competed for nutrients and light with upland rice and mungbean in the alley. He found that competition was severe in the 2-3 rows closest to the hedgerows, while yields were reduced by 47-95 percent and 11-37 percent for rice and mungbean, respectively.

Miah *et al*. (1995) reported that the mean light availability on crop rows decreased as they approached the tree rows across the alleys. The rate of decrease was greater in unpruned than in pruned alleys. Rice and mungbean yield decreased linearly with the reduced percent light incidence, rice yields decreased 47 kg/ha and mungbean yields decreased 10 kg/ha. In pruning regimes, mungbean yields decreased more in pruned conditions (13 kg/ha) than in unpruned condition (9 kg/ha).

Wainwright (1995) reported that the biomass of intercropped amaranth (*Amaranthus cruentus*) plants was less than that of pot grown plants. The spatial variation of the biomass of ground-grown plants at 82 stems ha^{-1} increased with distance from the oil palm tree. In a controlled shade experiment showed that amaranth could be grown successfully under low light levels and that biomass was not reduced relative to the controls at light levels up to 58 percent of total PAR. Prediction was made about optimal tree spatial arrangement in relation to crop biomass and transmitted PAR in agroforestry.

Solanki (1998) stated that fruit trees and crops are grown together in various ways. Depending on the pattern and configuration, these companion crops are known as intercrops, under planting, hedgerow planting or alley cropping. In an agroforestry systems where agricultural crops are normally grown between rows of fruit trees, the agricultural crops provide seasonal revenue, whereas fruit trees managed for 30-35 years giving regular returns of fruit and in some cases fuel wood from pruned wood and fodder. Several kinds of crops are also under planted to take the advantage of shade provided by the canopy of fruit trees.

Ali (1994) concluded that red amaranth and lady's finger could be grown successfully under drumstick tree although 10-15 percent yield was reduced compared to the open field.

From a Jackfruit-pineapple agroforestry system, Hossain (1999) estimated (made by using the models developed through the regression analysis) that the yield of pineapple would be maximized (64 t/ha) at a mean-season PAR of 610 M mol m^{-2} s^{-1} or 55 percent of open field condition. Such a light condition occurs in jackfruit orchards with an estimated crown cover of 9803 in m^2 ha^{-1}.

Singh *et.al*. (1989) concluded that shading was responsible for suppression of maize yields while in the shorter second season, where rains ended abruptly, moisture competition was the main factor causing the drastically low yield.

Importance of Studied Winter Vegetables

Vegetables are usually recognized as cheap, easily available sources of carbohydrates, proteins, minerals and vitamins. Importance of five studied winter vegetables such as cabbage, carrot, radish, tomato and eggplant are as follows:

Cabbage : The cabbage (*Brassica oleracea* var. capitata Linn.) is an important winter vegetable crop of Bangladesh. The climatic adaptability of the crop is so wide that its commercial cultivation is possible over a wide range of temperature, varying from 5 to 21° C. A long period of cold treatment induce the plants to bolt sooner and flower more abundantly (Rashid, 1976). In Bangladesh, winter is very short but is long enough for cabbage heads to mature. In 96-97, total production of cabbage was 106655 m ton from 26425 acre land which was the third highest production of winter vegetable in Bangladesh of that year (Anon., 1998).

It is mostly employed as culinary and dietic. It is used alone or mixed with potatoes for vegetable purposes. It is also used in curries, pickles etc. It may be used for feeding stock and chicken. `Sauerkraut' a favourite food in Russia, Germany and U.S.A., is made by fermenting chopped, ground, or sliced cabbage in its own juice, with a little salt added to it (Chauhan, 1989). From the nutrition point of view, it ranks very high.

According to Chatfield (1954) Watt & Merrill (1964), it contains the following nutrients per 100 grams fresh edible portion:

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Water	92.1 gm	Vit. E.	0.7 mgm
Protein	1.4 gm	FA	0.8 mgm
Total Fats	0.2 gm	Na	13 mgm
Total Carbohydrate	5.7 gm	K	227 mgm
Fibre	1.5 gm	Ca	46 mgm
Vitamin A	70 IU	Mg	23 mgm
Vitamin B_1	0.05 mgm	Fe	0.5 mgm
Vitamin B_2	0.04 mgm	P	28 mgm
Vitamin B_6	0.11 mgm	Cl	87 mgm
Vitamin C	46.00 mgm		

Carrot : Carrot (D*aucus carota*) is one of the most important carotene-rich root crops (Chowdhury, 1979). It is taken raw as well as cooked in curries. It is used in preserves, pickles, and sweetmeats. It is also used for making Halwa, Gajar Pak, and Carrot Pudding (Gajrela) which is very popular dessert (Chauhan, 1989). Malnutrition is a servere problem of Bangladesh, where children have clinical signs of vitamin A deficiency, and more than 900,000 children under 6 years of age suffer some degree of xerophthalmia and over 30,000 children go blind each year due to severe vitamin A deficiency (Siddiqui, 1998). To prevent this problem carrot can play a significant role as it contains high nutritional values. According to Watt and Merrill (1964), fresh carrot contains the following nutrients per 100 grams edible portion:

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Water	88.6 gm	Vit. E	0.45 mg
Protein	1.1 gm	Biotin	0.003 mg
Fat	9.1 gm	FA	0.008 mgm
Total Carbohydrate	9.1 gm	K	31.1 mgm
Fibre	1.0 gm	Ca	39.0 mgm
Vitamin A	12000 IU	Mg	21.0 mgm
Vitamin B_1	0.06 mgm	Fe	0.8 mgm
Vitamin B_2	0.06 mgm	P	37.0 mg
Vitamin B	60.12 mgm	S	21.0 mg
Nicotinic acid	0.5 mgm	Cl	40.0 mg
Vit. C	2-10 mg		

Radish: Radish (*Raphanus sativus* L.) is a popular vegetable in both tropical and temperate regions. This root vegetable is one of the major winter vegetables of Bangladesh. Radish is the first major winter vegetable crop in Bangladesh in respect of both area and production (B.B.S. 1998). In the year of 1996-97, 198895 metric ton of radish were produced from 53530 acre land, which was the maximum production of that year. It is eaten both raw, with salt or as salad, pickle, morabba, or as vegetable curry. According to Purewal (1957), it is cooling in effect, prevents constipation, increases appetite and is very tasteful when both roots and leaves are cooked together. According to Chatfield (1949 and 1954) fresh radish roots contain the following nutrients per 100 grams edible portion :

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Water	93.7 gm	Calcium	37 mgm
Protein	1.1 gm	Phosphorus	31 mgm
Fat	0.1 gm	Potassium	260 mgm
Carbohydrate	4.2 gm	Magnesium	15 mgm
Fibre	0.7 gm	Sulphur	37 mgm
Vitamin A	30 I.U.	Chlorine	37 mgm
Vitamin C	24 mgm	Iron	1.0 mg

Nutrient contents in leaf are as follows (Aykroyd, 1941).

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Water	89.1 gm	Vit. A	8 I.U.
Protein	3.9 gm	Vit. B	21 gmg
Fat	0.6 gm	Vit. C	21 mgm
Carbohydrate	4.1 gm	Nicotinic acid	1.4 mgm
Ca	.31 gm	Riboflavin	2.7 gmg
P	0.06 gm	100 gm	
Fe	.8 mgm		

Tomato : Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular winter vegetables of the solanaceae family. It is the world's most widely grown vegetable crop after potato and sweet potato and it tops the list of canned vegetables (Patwary, 1997). Tomato is a day neutral but thermosensitive crop. Its cultivation is restricted mostly during winter. Plants set fruit abundantly when the night temperature is 20 ^{o} C (Rashid, 1993). In Bangladesh, the optimum temperature exists only 3-4 months in a year. So tomato is usually grown here in rabi season. Some summer tomato varieties have been released by BARI and BINA but their performance were unsatisfactory at farmers fields because of some unfavourable climatic factors, particularly temperature, rainfall etc. Again, high light intensity also causes fruit burn. Partial shade from tree or in other means can solve fruit burn problem along with reducing air and soil temperature.

Since, tomato is a highly demanding crop and its production is far below than those of requirement, so attempt should be taken to increase the tomato production by reducing light through agroforestry system.

According to Nadkarni (1927), it has many medicinal uses. Tomato is popular due to its diversified use. It is cooked as a vegetables along or mixed with other vegetables. When it is ripe, it is also taken raw or is made into salads, soups, preserves, pickles, sauce, ketchups and many other products.

According to Chatfield (1949 & 1954) tomato fruit contain the following nutrients per 100 grams fresh edible portion :

Nutrients composition	Content (per 100 g of edible portion)	Nutrients composition	Content (per 100 g of edible portion)
Water	94.1 gm	Citric acid	390 mgm
Protein	1.0 gm	P	27 mgm
Fat	0.3 gm	S	27 mgm
Carbohydrate	4.0 gm	Cl	51 mgm
Fibre	0.6 gm	Oxalic acid	7.5 mgm
Vit. A.	1100 I.U	Na	3 mgm
Vit. B	0.20 mgm	K	268 mgm
Nicotinic acid	0.6 mgm	Ca –	11 mgm
Pantothenic acid	0.31 mgm	Mg	11 mgm
Vitamin C	23.00 mgm	Iron	0.6 mgm
Vit. E	0.27 mgm	Cu	0.10 mgm
Biotin	0.004 mgm	Mn	0.19 mgm
Malic acid	150 mgm		

Eggplant: The eggplant (*Solanum melongena* L.) is one of the principal vegetables commonly cultivated in Bangladesh. Eggplants are cultivated in about 28 thousand hectares of land in both rabi and kharif seasons with yearly production of approximately 182 thousand tons occupying the third position in respect of vegetable production in Bangladesh (Ahmed *et al.*, 1983). As winter vegetable, the production of rabi eggplant was 13.1 thousand tons in the year 1996-97 which was the second highest winter vegetable production of that year.

Eggplant is a strong garden herb, grown for its large fruits. It is of major importance as a commercial crop and is grown all over the Bangladesh. Contrary to the common belief, it is quite high in nutritive value and can well be compared with that of tomato. Nadharni (1927) has cited many medicinal uses of eggplant also. According to Dr. Aukroyd (1941), eggplant fruit contains the following nutrients per 100 grams edible portion:

Nutrients composition	Content (per 100 g of edible portion)
Water	91.5 gm
Protein	1.3 gm
Fat	0.3 gm
Carbohydrate	6.4 gm
Minerals .	5 gm
Ca	.02 mg
P	.06 mg
Fe	.0013 mg

CHAPTER III

MATERIALS AND METHODS

Location and Time of the Study

The experiment was conducted at the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University during November 1999 to March 2000 under upland condition. The University farm is located at Salna of Gazipur District, about 40 Km North from Capital Dhaka. The study site is located at 24^{o} 09' North Latitude and 90^{o} 26' East Longitude and situated at 8.20 m above the mean sea level (Anon., 1989).

Climate and Weather

The experimental site is characterized by a tropical climate where the hotter months are in summer (March to May) with the mean maximum temperature of 34 ^{o} C and the cooler months are in winter (November to January) with the mean temperature of 11.9 ^{o} C. Temperature during the monsoon season (June to September) is moderate. After the withdrawal of monsoon a decreasing trend in temperature is noticed in October with further decline in December and January. The relative humidity increases from April and reaches peak (80%) in July and decline thereafter up to March (55%). Mean annual rainfall is about 2070 mm, most of which occurs in short spells during the months of May to September. Light rains (amounting to an average of 310 mm) occurs in dry season (during October to

March). The total rainfall of the locality during the research period was 145.95 mm. The mean monthly minimum and maximum temperature for the month of November; December; January; February; March were 22.78 and 30.53; 19.49 and 29.62; 15.87 and 26.72; 18.03 and 27.81; 21.71 and 31.16° C, respectively, and the minimum and maximum relative humidity for those months were 47.02 and 91.57; 47.44 and 93.10; 38.67 and 93.84; 41.56 and 92.70; 37.38 and 90.89 percent, respectively. Weather data during study period are presented in fig 1.

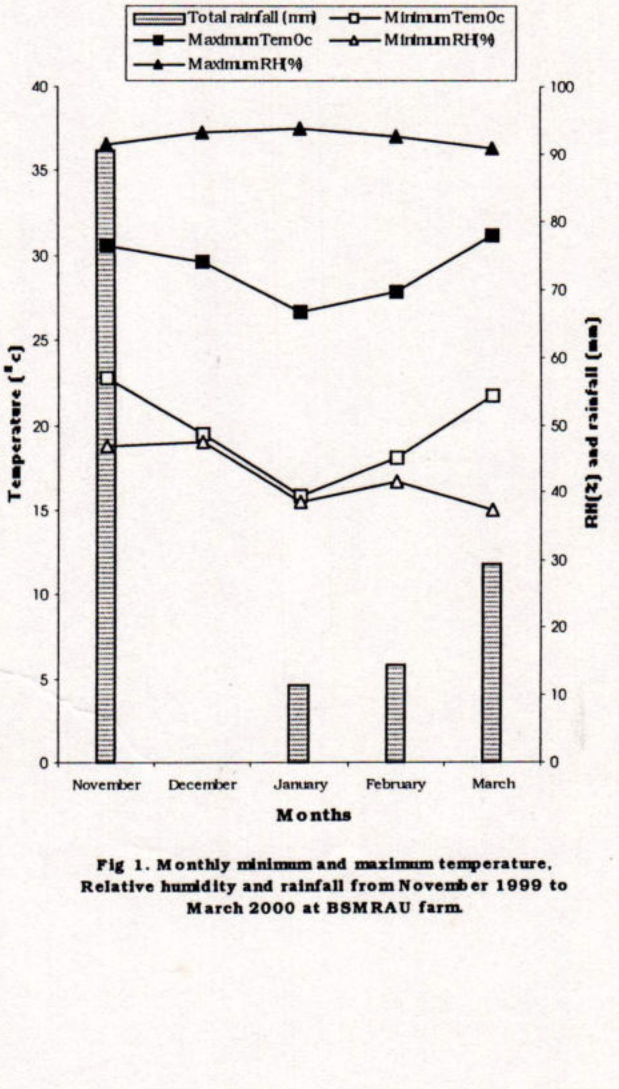

Fig 1. Monthly minimum and maximum temperature, Relative humidity and rainfall from November 1999 to March 2000 at BSMRAU farm.

Soil Characteristics

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 depositing recent alluvial soil i.e., the surface soil is artificial alluvial loam with red Madhupur clay underneath.

Experimental Design and Layout

Four vegetables such as Cabbage (*Brassica oleracea* var. Capitat Linn.), Carrot (*Daucus carota* L.), Radish (*Raphanus sativus* L.) and Tomato (*Lycopersicon esculentum* Mill.) were laid out in individual experiment following Randomized Complete Block Design (RCBD) and one vegetable such as eggplant (*Solanum melongena* L.) was laid out in split plot design. Three replications were followed in each experiment. In split plot design, different light levels were in main plot and eggplant varieties were put in to the sub plots. Individual plot size for cabbage, tomato and eggplant was 2.5 m x 2.5 m. For radish and carrot the plot size were 2 m x 1.5 m. Adjacent plots and neighboring blocks were separated by 2.5 m and 1.0 m, respectively.

Treatments of the Experiment

The following four treatments i.e. four different light levels were used in case of cabbage, carrot, radish and tomato for RCBD design:

T_1- 100 percent Photosynthetically Active Radiation (PAR) referred as open field/control,

T_2- 75 percent Photosynthetically Active Radiation (PAR),

T_3- 50 percent Photosynthetically Active Radiation (PAR), and

T_4- 25 percent Photosynthetically Active Radiation (PAR).

For eggplant the following treatments were used in split plot design:

Factor A : Aforementioned four light treatments were in main plot.

Factor B : Eggplant varieties were in sub-plot.

The varieties of eggplant were Nayantara, Kajla and Uttara.

In T_1 treatment, sunlight was allowed to fall over the vegetables without any barrier which was considered as 100 percent light. Light was recorded as PAR using sunfleck ceptometer (Model 800-755-2751). In T_2, T_3 and T_4 treatments, light levels in the form of PAR were reduced to 75 percent, 50 percent and 25 percent, respectively, using mosquito nets considering open field light as 100 percent PAR. For this purpose, mosquito nets of different pore sizes available in the different markets of Dhaka city were collected and light (PAR) transmission ability of those nets were examined. Among the different sizes of nets, three different pore sizes were selected through which 75 percent, 50 percent and 25 percent of PAR could be transmitted, respectively. The selected nets were set above the plots and transmitted light (PAR) beneath the net was measured again by Ceptometer AccuPAR.

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.

Net Setting

After laying out the experimental plots, mosquito nets of different sieve sizes were hanged up to a height of 1.5 meters over the T_2, T_3, and T_4 plots for maintaining 75 percent, 50 percent, and 25 percent PAR, respectively, with the help of bamboo sticks. No net was used in the control (T_1) plots.

Crop Establishment

Among the five vegetable species, carrot and radish seeds were directly sown in the experimental plot on 30^{th} November 1999. Tomato, cabbage and eggplant seeds were sown on 30^{th} October 1999 for raising seedling in separate seed bed. The seedlings of cabbage, tomato and eggplant were transplanted on 30^{th} November 1999 maintaining the spacing of 60 cm X 50 cm, 60 cm X 40 cm and 60 cm X 50 cm, respectively. Carrot and radish seeds were sown continuously at 25 cm and 30 cm apart lines, respectively. After emergence, carrot and radish plants were thinned out by maintaining 10 and 15 cm distances from plant to plant, respectively.

Management Practices

Fertilizer application

Recommended doses of fertilizers (BARC, 1999) were used for the respective vegetable species. Fertilizer doses for cabbage, carrot, radish, tomato and eggplant were 4 ton - 130 kg - 25 kg – 100 kg, 4 ton - 120 kg - 25 kg - 90 kg, 4 ton -130 kg - 20 kg - 70 kg, 5 ton - 140 kg - 30 kg - 100 kg and 5 ton - 100 kg -20 kg –90 kg as cowdung, N, P and K per hectare, respectively.

All cowdung, P, K and one third of N were applied and incorporated during the final land preparation for radish and carrot. For both crops, the remaining N was side dressed in two equal instalments at 21 and 35 days after sowing. For cabbage and tomato, full amount of cowdung and P were incorporated during final land preparation. Nitrogen and K were applied in two equal instalments at 15 and 35 days after transplanting.

In case of eggplant, full cowdung, P and half of the N and K were applied at the time of final land preparation. The remaining N and K were applied in two equal instalments at the time of flowering and fruiting.

Weeding and Irrigation

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.

Harvesting

Cabbage was harvested at 60 days after transplanting of seedlings, just after the heads reached marketable size. Carrot was harvested at 110 days after sowing when the carrot reached at marketable size. Radish was harvested at 57 days after seed sowing. Tomato was harvested in several pickings when the fruits appeared at just yellow color. The tomato was harvested during 90 to 115 days after planting (DAP). Eggplant harvesting started at 92 days of planting and continued up to 125 days after planting. Eggplant fruits were also harvested in several pickings when the fruit attain standard size for marketing.

Sampling Procedure and Data Collection

Cabbage

Ten representative plant samples of cabbage were collected randomly from all rows of each plots. These sample plants were used for data collection. The data collected from the sample plant were outer leaf length, outer leaf breadth, number of outer leaves per plant, fresh weight, dry weight of outer leaves, head length, head breadth, head fresh and dry yield. The yield per plant was converted to ton/ha. For dry yield, 100 g subsamples were oven dried at 70 °C for 72 hours. Total dry yield was calculated using the following formula:

$$\text{Total dry weight (yield)} = \frac{\text{subsample oven dried weight}}{\text{subsample fresh weight}} \text{ X total fresh weight}$$

Carrot

Carrots were collected randomly from all rows of the respective plots. Ten representative sample plants of carrot were selected from each plot for data collection. Samples plants were collected at 110 days after sowing i.e. time of final harvesting for measuring plant height, number of leaf per plant, leaf length, leaf dry weight, carrot length, carrot diameter, carrot yield. All these parameters were recorded using the same procedure like cabbage.

Radish

Plant samples of radish were collected randomly from all rows of the respective plots. Ten representative sample plants were selected from each plot for data collection. Sample plant were collected at 57 days after sowing i.e. at the time of final harvest for recording plant height, number of leaf per plant, leaf length, leaf breadth, leaf dry weight per plant, radish (root) length, radish girth and yield.

Tomato

Plant samples of tomato were collected randomly from all rows of the respective plots. Ten plants of tomato were selected from each plot for data collection. Plant height, number of primary branches per plant, number of leaf per plant and number of cluster per plant were determined from the sample plant during final harvesting. Number of fruit per plant, number of fruit per cluster, fruit diameter and fruit weight were measured when fruits attained to edible size. Fresh yield was determined from summation of each fruit weight of a plant and then converted to ton/ha.

Eggplant

Plant samples of eggplant were collected randomly from all rows of the respective plots. Five plants of eggplant were selected from each plot for data collection. Plant height, number of primary branches per plant, number of total branches per plant and number of leaves per plant were recorded at the time of final harvesting. Number of fruit per plant, fruit length, fruit diameter and fruit weight were measured when fruit attained its edible size. Fresh yield was determined from summation of each fruit weight of a plant and then converted to ton/ha.

Data Analysis

The data on various growth and yield contributing characters of the five tested vegetables were statistically analyzed to examine the significant variation of the results due to different light treatments. 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 Duncan Multiple Range Test (DMRT) at 5 percent level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The performances of the five winter vegetables grown under different light levels are presented and discussed in this chapter separately for each vegetable.

Performance of Cabbage

Outer leaf length

Length of outer leaf of cabbage plant was increased gradually with the increased of shade levels. The longest leaf was found under heavy shade i.e. 25 percent PAR (42.00 cm) which was statistically similar to that of 50 percent PAR (41.5 cm) and 75 percent PAR (40.00 cm). Significantly the shortest leaf was recorded under full sunlight i.e. 100 percent PAR (37.28 cm). Outer leaf of the cabbage cultivated under shade grew more vigorously than those in the open field. This may be attributed due to the stimulation of cellular expansion and cell division of outer leaf under shaded conditions (Schoch, 1972).

Outer leaf breadth

Outer leaf breadth of cabbage increased insignificantly as the light level decreased up to a certain level (50% PAR). Further decreased of light levels, leaf breadth drastically decreased. The highest leaf breadth was recorded under 50 percent PAR (30.98 cm) which was statistically similar to that of 75 percent PAR (30.13 cm) and 100 percent PAR (29.15 cm). Significantly the lowest leaf breadth was observed under 25 percent PAR (26.85 cm) level.

Number of outer leaf

The number of outer leaf per plant varied significantly with the variation of light levels. Significantly the highest number of outer leaf per plant was observed under 25 percent PAR (17.63) which was followed by 100 percent PAR (16.61) and 75 percent PAR (15.95). The number of outer leaf found under 75 percent and 100 percent PAR were statistically similar. Significantly the lowest number of outer leaf was recorded under 50 percent PAR (14.42). This may be occurred due to the modification of maximum inner leaf in head formation.

Outer leaf weight

Fresh weight : Fresh weight of outer leaf per plant was also affected by different light levels (Table 1). The highest leaf fresh weight per plant was recorded under 75 percent PAR (739.69 g) which was statistically identical to that of 100 percent PAR (663.34 g) and 50 percent PAR (680.76 g). This may be attributed due to maximum rates of net photosynthesis under partial shaded conditions. Significantly the lowest leaf fresh weight per plant was recorded under 25 percent PAR (436.18 g).

Table 1. Growth characters of cabbage under different light levels

Light level (%PAR)	Outer leaf length (cm)	Outer leaf breadth (cm)	Number of outer leaf/plant	Outer leaf fresh weight (g)	Outer leaf dry weight (g)
100	37.28 b	29.15 a	16.61 b	663.34 a	48.49 a
75	40.00 a	30.13 a	15.95 b	739.69 a	54.91 a
50	41.50 a	30.98 a	14.42 c	680.76 a	51.19 a
25	42.00 a	26.85 b	17.63 a	436.18 b	33.21 b

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Dry weight: Dry weight of outer leaf per plant showed the similar trend to the outer leaf fresh weight per plant. The highest leaf dry weight per plant was recorded under 75 percent PAR (54.91 g) which was followed by 50 percent PAR (51.19 g) and 100 percent PAR (48.49 g). The lowest dry weight of outer leaf was recorded under 25 percent PAR (43.21 g).

Head length

The important yield contributing character of cabbage is head length. Head length was affected by the different light levels (Table 2). The length of head gradually (but insignificantly) increased up to 50 percent reduced light level. With the further increased of shade level (decreased of PAR levels), head length drastically decreased. The largest cabbage head was recorded under 50 percent

PAR (16.04 cm) which was identical to that of 75 percent PAR (15.54 cm) and 100 percent PAR (15.10 cm). The lowest head length was observed under 25 percent PAR (13.35 cm).

Head breadth

Head breadth was significantly affected by the different light levels (Table 2). Minimum head breadth (9.76 cm) of cabbage was found under maximum shade condition (25% PAR). But head breadth under any of the other three treatments i.e. 50 percent PAR (15.29 cm), 75 percent PAR (15.25 cm) and 100 percent PAR (15.13 cm) did not vary statistically.

Head weight

Fresh weight : Influencing pattern of different light levels on the fresh weight of head per plant was similar to the head length. Head fresh weight progressively increased up to 50 percent reduction of light levels. With the further reduction of light level, head fresh weight drastically decreased. The highest fresh weight of head per plant was observed under 50 percent PAR (599.44 g), followed by 75 percent PAR (595.58 g) and 100 percent PAR (577.55 g). Significant the lowest yield (head fresh weight) per plant was recorded under 25 percent PAR (246.57 g). The lowest head fresh weight per plant at 75% shaded condition may be due to lower production of photosynthates under low light condition for a longer period (Miah *et al.,* 1999).

Weight : The head dry weight per plant (dry yield/plant) had shown similar trend to the head fresh weight. The highest head dry weight per plant was recorded under 50 percent PAR (38.13 g) which was statistically similar to that of 75 percent PAR (34.5 g) and 100 percent PAR (34.45 g). The lowest head dry weight per plant was found under 25 percent PAR (16.93 g).

Total yield

Fresh yield : Marketable yield of cabbage (ton/ha) was significantly influenced by different light levels (Table 2). Fresh yield (t/ha) showed the similar trend to that of individual head fresh weight. Partial shade condition had positive effect on the yield of cabbage. Marketable total yield gradually increased up to 50 percent reduction of light levels. Further reduction of PAR level, yield decreased drastically. The highest yield was recorded under 50 percent PAR (29.98 t/ha) which was statistically similar to that of 75 percent PAR (29.52 t/ha) and 100 percent PAR (28.92 t/ha). Similarly, the highest yield of head cabbage under 30-47% shaded condition was found by Wolff and Coltman (1990). Significantly the lowest yield was recorded under 25 percent PAR (12.55 t/ha).

Table 2. Yield and yield contributing characters of cabbage under different light levels

Light level (%PAR)	Head length (cm)	Head breadth (cm)	Head fresh weight (g)	Head dry weight (g)	Fresh yield (t/ha)	Dry yield (t/ha)
100	15.10 a	15.13 a	577.55 a	34.45 a	28.92 a	1.72 a
75	15.54 a	15.29 a	595.58 a	34.50 a	29.52 a	1.89 a
50	16.04 a	15.25 a	599.44 a	38.13 a	29.98 a	1.90 a
25	13.35 b	9.76 b	246.57 b	16.93 b	12.55 b	0.84 b

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Dry yields : The total dry yield (t/ha) of cabbage had showed similar pattern to fresh yield of cabbage. The highest dry yield of head was found under 50 percent PAR (1.90 t/ha) which was followed by 75 percent PAR (1.89 t/ha). The lowest yield was recorded under 25 percent PAR (0.84 t/ha).

Relationship between light level and fresh yield of cabbage

The relationship between fresh yield of cabbage and light (% PAR) showed a quadratic polynomial equation as $Y = -0.0072 X^2 + 1.0964 X - 9.4675$ ($R^2 = 0.8882$), where R^2 value is high and highly significant (Fig. 2). The R^2 value indicate that about 89 percent of total variation in the mean fresh yield of cabbage

(Head) can be explained by the above quadratic regression equation. This equation also stated that the yield of cabbage was maximum i.e. 32.26 ton/ha at 76 percent PAR level, and beyond this PAR level (76%) cabbage yield decreased at the rate of 0.0072 t/ha for per unit changing of percent PAR. The equation also express that 24% shading level increased cabbage yields by 14.59% compared with full sunlight. Almost similar relationship was found by Wolff and Coltman (1990). They reported 30-47% shading increased head yields of cabbage and Chinese cabbage by 23% and 21%, respectively, compared with full sun light plots.

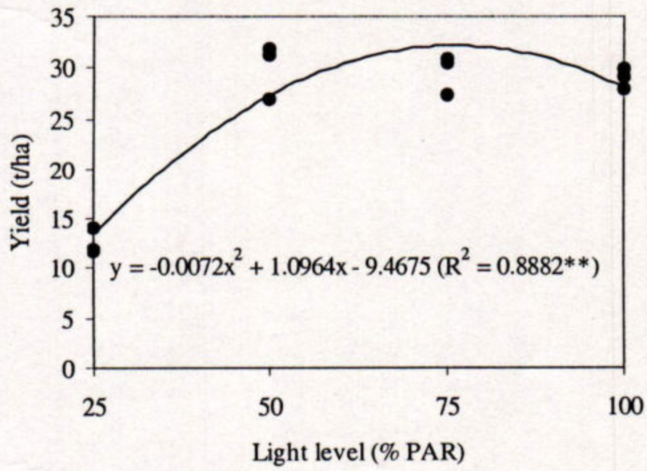

Fig. 2. Relationship between light level (% PAR) and yield of cabbage

Performance of Carrot

The influence of different reduced light levels on the growth, yield contributing characters and yield of carrot is presented in Table 3 and 4.

Plant height

Carrot cultivated under shade grew more vigorously than those cultivated in the open field. It exhibited significantly higher height under the all shaded treatments where the tallest plant (70.49 cm.) was obtained under the heaviest shade conditions (25% PAR) and the shortest plant (51.84 cm.) was recorded under the full sunlight. However, no significant variation on plant height was observed between 75 percent (67.91 cm.) and 50 percent (69.59 cm.), between 50 percent and 25 percent (70·49 cm) PAR levels. Similarly, higher plant height under reduced light levels was observed in mungbean (Ali, 1998; Islam, 1996) and in chickpea (Murshed, 1996). This may be attributed due to the stimulation of cellular expansion and cell division under shaded conditions (Schoch, 1972).

Leaf number

The number of leaf per plant of carrot were significantly influenced by the different light levels (Table 3). It has been showed that carrot grown under 75 percent PAR level produced significantly the highest number of leaf per plant (18.73) as compared to other light treatments. Carrot grown under 50 percent (17.17) or 100 percent PAR (17.17) did not show significant variation in terms of number of leaf per plant. Carrot grown under heavy shaded level i.e. 75 percent shade (25% PAR) was found to produce significantly the lowest number of leaf per plant (12.93) as compared to other light levels. Similar results were also reported by Ali (1999) and Wadud (1999). The lower number of leaf per plant at the reduced light conditions may be due to lower production of photosynthates under low light conditions for a longer period (Miah *et. al,* 1999).

Leaf length

The length of the leaf of carrot was increased gradually as the light levels decreased or shade levels increased. The leaf length of carrot was significantly affected by the different light levels. The shorted leaf (37.76 cm) was found at full sunlight (100% PAR) which was statistically much was shortage than those of the other light treatments. Significantly the longer leaf length was recorded under 25 percent PAR (56.5 cm). Leaf length produced under 75 and 50 percent PARs was intermediate and statistically similar to each other.

Leaf dry weight

Leaf dry weight per plant of carrot was significantly influenced by the different reduced light levels also (Table 3). The values of leaf dry weight per plant were recorded at different light levels showed similar pattern of varieties as the number of leaf per plant.

Table 3. Growth characters of carrot under different light levels

Light level (%PAR)	Plant height (cm)	No. of leaf / plant	Leaf length (cm)	Leaf dry weight (gm)
100	51.84 c	17.17 b	37.76 c	10.05 b
75	67.91 b	18.73 a	50.33 b	12.31a
50	69.59 ab	17.17 b	52.81b	10.55 b
25	70.49 a	12.93 c	56.5 a	5.84 c

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Carrot (root) length

The length of the carrot was significantly influenced by the different light levels. The longest carrot length (17.59 cm.) was observed under 75 percent PAR which was statistically similar to that of 50 percent PAR (16.27 cm.) The shortest carrot length (13.98 cm.) was recorded under 75 percent reduced light which was statistically similar to that of full sunlight (14.59 cm).

Carrot diameter

Carrot diameter was also affected by different reduced light levels (Table 4). The highest carrot diameter (29.34 mm) was observed under 75% PAR level which was statistical similar to 100% PAR level (28.727 mm). From 75 percent PAR, carrot diameter decreased significantly with the decreased of PAR levels and the lowest carrot diameter (19.62 mm) was recorded under 25 percent PAR. The lowest carrot diameter at the heaviest light level may be associated with the lower mobilization of reserve assimilates to storage organ. Similar mobilization rate was found by Ali (1998) and Laosuwan *et al.,* 1992 in mungbean.

Table 4. Yield and yield contributing characters of carrot under different light levels

Light level (% PAR)	Carrot length (cm)	Carrot diameter (mm)	Carrot yield	
			(gm/plant)	(ton/ha)
100	14.59 b	28.27 a	67.45 b	26.98 b
75	17.59 a	29.34 a	76.74 a	30.6 a
50	16.27 a	26.19 b	68.12 b	27.25 b
25	13.98 b	19.62 c	35.16 c	14.06 c

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Carrot yield

Carrot yield per plant was significantly affected by the different light levels. The yield under 75 percent PAR level was much more higher (76.74 gm) than those obtained from the other light treatments. Significantly the highest carrot yield per plant under 75 percent PAR was attributed by the higher length and diameter of carrot as compared to other light treatments. Similar result was found by Jayachandran *et al.,* 1992 on production of zinger in India. The yield of carrot per plant under full sunlight and 50 percent PAR (65.45 gm and 68.12 gm, respectively) were statistically similar. The carrot yield produced under 25 percent PAR level (35.6 gm) was significantly much lower than those of other light levels and it was only 54.11 percent, 45.81 percent, and 51.60 percent as compared to the yield produced under 100 percent, 75 percent and 50 percent light levels, respectively. The lowest yield under relatively more and prolong shaded condition was probably due to poor photosynthetic capacity of plants. The decrease in photosynthetic capacity of shaded plant was attributed to both stomatal and mesophyl cell properties (Woledge, 1977).

The relatively better yield of carrot under 25 percent shade level (75% PAR) might be due to better photosynthetic efficiency of carrot plants under partial shade condition. It has been postulated that partial shading increased the quantity of chlorophyll and thus increased the photosynthetic efficiency of the plants (Collord *et al.*,1977; El-Aidy *et al.*,1983). Nayak *et al.*, 1979 reported that translocation is enhanced under slightly reduced light (70% of normal light), but further reduction in light (below 70% of normal light) affect translocation due to limitation in energy supply.

Carrot yield per plant was converted to total yield in ton/ha. The total yield of carrot (ton/ha) showed almost similar pattern of variations among the four light levels as carrot yield per plant. Significantly the highest yield obtained under 75 percent PAR was 30.69 ton/ha. The yield under 50 percent PAR (27.25 ton/ha) and 100% PAR (26.98) was statistically similar, though yield under 50% PAR was numerically higher. Significantly the lowest yield found under 25% PAR was 14.06 ton/ha.

Relationship between light and yield of carrot

A quadratic polynomial relationship was found between yield of carrot and light (% PAR) which was represented as $Y=-0.0068X^2 +1.0138X -6.9267$ ($R^2 =0.9697$), where the R^2 value was very high and highly significant (Fig. 3). The R^2 value indicated that 96.97 percent of the contribution to the yield of carrot could be explained by percent PAR. This equation also stated that yield of carrot was maximum i.e., 30.8583 t/ha at 75 percent PAR level and beyond this PAR carrot yield decreased at the rate of 0.0068 t/ha for per unit changing of percent PAR.

Using this equation it was indicated that carrot yield did not decrease significantly up to 53 percent light reduction (47% PAR) i.e. Kuroda-35 variety of carrot can be grown up to under 47 percent PAR level in rabi season without significant yield loss.

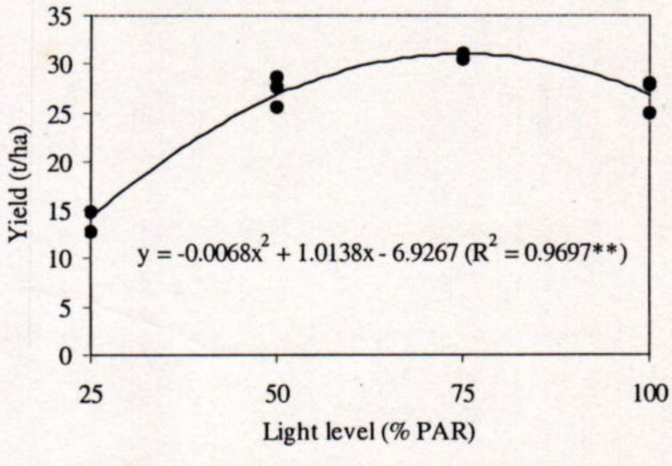

Fig. 3. Relationship between light level (% PAR) and yield of carrot

Performance of Radish

Leaf number

Number of leaf per plant of radish grown under different light levels was affected significantly (Table 5). The maximum number of leaf per plant (18.54) was recorded under 75 percent PAR which was statistically similar to that of 100 percent PAR (16.61) and 50 percent PAR (15.39) levels. The lowest number of leaf per plant was found under 25 percent PAR (14.64) which was also statistically identical to that of 100 percent and 50 percent PAR levels. The lower number of leaf per plant at the reduced light conditions may be due to lower production of photosynthates under low light conditions for a longer period (Miah *et al.* (1999).

Leaf length

Radish cultivated under shade grew more vigorously than those in open field. It exhibited significantly the shortest leaf length under full sunlight (27.11 cm). The longest leaf was found under 25 percent PAR (43.56 cm) which was statistically similar to that of 50 percent PAR (42.56 cm). The leaf length produced under 75 percent PAR was 35.99 cm which was significantly higher than that of 100 percent PAR (27.11 cm) but significantly lower than that of 50 percent PAR (42.56 cm). Similar influencing pattern in plant height of okra under reduced light levels was reported by Wadud (1999).

Leaf breadth

The leaf breadth of radish was increased gradually as the light levels decreased or shade level increased. The highest leaf breadth found under 25 percent PAR was 10.24 cm which was statistically identical to that of leaf breadth produced under 75 percent PAR (10.17 cm) and 50 percent PAR (9.23 cm). Significantly the lowest leaf breadth observed under full sunlight (100% PAR) was 7.51 cm.

Leaf dry weight

Leaf dry weight per plant was also influenced by the different light levels (Table 5). Significant the lowest leaf dry weight was observed under 100 percent PAR (5.42 g). The leaf dry weight produced under 75 percent PAR (7.79 g) was significantly the highest which was statistically similar to that of 50 percent PAR (7.54 g) and 25 percent PAR (7.39 g). Similarly the highest weight of leaf per plant under 75% PAR in kangkong was observed by Wadud (1999).

Table 5. Growth characters of radish under different light levels

Light level (% PAR)	No. of leaf per plant	Leaf length (cm)	Leaf breadth (cm)	Leaf dry weight/ plant (g)
100	16.61 ab	27.11 c	7.51 b	5.42 b
75	18.54 a	35.99 b	9.23 a	7.79 a
50	15.39 ab	42.56 a	10.17 a	7.54 a
25	14.64 b	43.56 a	10.24 a	7.39 a

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Radish (root) length

The length of radish (root) was also influenced by the reduced light levels (Table 6). The highest radish length was obtained under 75 percent PAR (16.25 cm) which was followed by 100 percent PAR (14.89 cm) and 50 percent PAR (14.20 cm). The radish length produced under 25 percent PAR was significantly the lowest (9.05 cm).

Radish (root) girth

The radish girth or circumference was greatly affected by different light levels. The maximum girth value of radish was recorded under 75 percent PAR (12.9 cm) which was identical to the value of 100 percent PAR (12.05 cm). Reduction of light levels from 75 percent to 25 percent PAR had decreased the radish girth significantly. The radish girth recorded under 50 percent PAR and 25 percent PAR were 9.64 cm and 7.42 cm, respectively. The lowest radish girth under shaded conditions may be associated with the lower mobilization of reserve assimilates to storage organ. Similar mobilization rate was observed by Ali (1998) and Laosuwan *et al.,* 1992 in mungbean.

Yield

Radish (root) yield per plant was significantly influenced by different light levels. Significantly the highest radish yield per plant was found under 75 percent PAR (152.33 g). At 100 percent PAR, the radish yield was 135.75 gm per plant, which was statistically higher than that of 50 percent PAR (110.46 gm/plant).

Significantly the lowest radish yield (34.22 gm/plant) was found under 25 percent PAR. Relatively the better yield of radish (root) under 25 percent shade level (75% PAR) might be due to better photosynthetic efficiency of and faster translocation of photosynthates in storage organ of radish plants under partial shade condition. It has been postulated that partial shading increased the quantity of chlorophyll and thus increased the photosynthetic efficiency the plants (Collord *et al.*, 1977; El-Aidy *et al.*, 1983).

The radish (root) yield per plant was converted to total yield in ton/ha. The total yield of radish root (ton/ha) showed almost similar pattern of variations among the four light treatments as radish (root) yield per plant. Significantly the highest yield recorded under 75 percent PAR was 33.85 ton/ha. The yield of radish at full sunlight was 30.16 ton/ha, which was statistically higher than that of 50 percent PAR (24.54 ton/ha). Significantly the lowest yield of radish recorded under 25% PAR was 7.60 ton/ha.

Table 6. Yield and yield contributing characters of radish under different light levels

Light level (%PAR)	Radish length (cm)	Radish girth (cm)	Yield per plant (g)	Yield (t/ha)
100	14.89 a	12.05 a	135.75 b	30.16 b
75	16.25 a	12.90 a	152.33 a	33.85 a
50	14.20 a	9.64 b	110.46 c	24.54 c
25	9.05 b	7.42 c	34.22 d	7.60 d

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Relationship between fresh yield of Radish and light level (% PAR)

The relationship between fresh yield of radish and light levels (% PAR) showed a quadratic polynomial equation as $Y = -0.0082\ X^2 + 1.3392\ X - 20.993$ ($R^2 = 0.9868$), where the R^2 value was very high and highly significant (Fig. 4). The R^2 value indicated that about 99 percent of the contribution to the yield of radish could be explained by percent PAR. This equation also stated that yield of radish was maximum i.e. 33.05 ton/ha at 81 percent PAR level, and beyond this PAR level (81%) radish yield decreased at the rate of 0.0082 ton/ha for per unit changing of percent PAR.

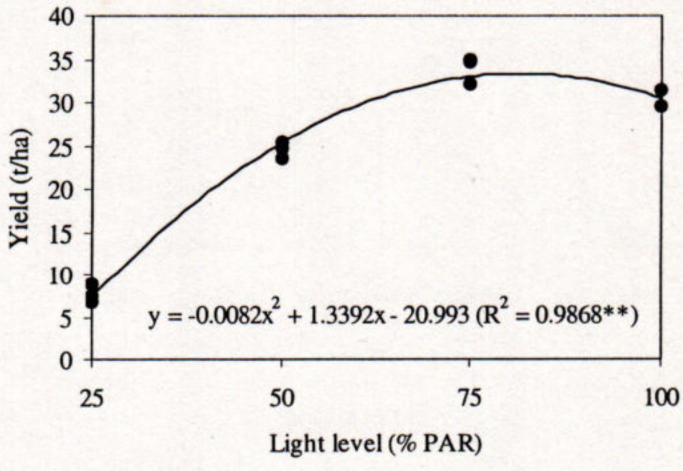

Fig. 4. Relationship between light level (% PAR) and yield of radish

Performance of Tomato

Plant height

Tomato plant cultivated under shade grew more vigorously than those grew in the open field. It exhibited significantly longer height irrespective of shaded treatments. With the increased of shade levels (decreased of PAR levels), plant height increased significantly. The shortest plant was found under 100 percent PAR (58.53 cm) and the tallest plant (107.49 cm) was recorded under the heaviest shade condition (25% PAR). Plant height observed under 75 percent and 50 percent PAR level was 74.33 and 93.58 cm, respectively. Significantly taller plant height under heavy shade in okra was reported by Ali (1999). Plant grown in low light levels was found to be more apically dominant than those grown in high light environment resulting in taller plants under shade (Hillman, 1984).

Number of primary branch

Primary branches per plant was influenced by reduced light levels (Table 7). Number of primary branches per plant was also decreased gradually with the increased of shade levels. The maximum number of primary branches (3.27) obtained under full sunlight (100% PAR) was statistically identical to 75 percent PAR (3.20) and 50 percent PAR (3.17) levels. Significantly the lowest number of primary branch was recorded under 25 percent PAR (2.47) level compared to other treatments. The lower number of primary branches under shaded conditions 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).

Table 7. Growth characters of tomato under different light levels

Light level (%PAR)	Plant height (cm)	Number of primary branches/ plant	Number of leaf/plant	Number of cluster/plant
100	58.53 d	3.27 a	64.10 b	9.70 ab
75	74.33 c	3.20 a	78.97 a	10.83 a
50	93.58 b	3.17 a	59.83 b	9.90 ab
25	107.49 a	2.47 b	54.90 b	8.30 b

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Leaf number

Number of leaf per plant was significantly influenced by reduced light levels (Table 7). Significantly the highest number of leaf per plant (78.97) was recorded under 75 percent PAR. The second highest number of leaf per plant was observed under 100 percent PAR (64.10) which was statistically similar to that of 50 percent PAR (59.83) and 25 percent PAR (54.9). Similar result was also reported by Ali (1999). The lower number of leaf per plant at the reduced light conditions may be due to lower production of photosynthates under low light conditions for a longer period (Miah *et al.,* 1999).

Number of cluster

The highest number of cluster per plant (10.83) was recorded under 75 percent PAR which was statistically similar to that of 100 percent PAR (9.70) and 50 percent PAR (9.90). Significantly the lowest number of cluster per plant was recorded under 25 percent PAR (8.3) which was also identical to that of 50 percent PAR and 100 percent PAR.

Number of fruit per plant

Number of fruit per plant is the most important yield contributing character which was also significantly influenced by different light levels. The maximum number of fruit per plant was found under 75 percent PAR (33.13) which was statistically similar to that of 100 percent PAR (31.2) and 50 percent PAR (30.67). The minimum number of fruit per plant was recorded under 25 percent PAR (23.27) which was also statistically identical to that of 50 percent PAR (30.67). The lower number of fruits per plant under relatively more and prolong shaded condition was probably due to poor photosynthetic capacity of plants. The decrease in photosynthetic capacity of shaded plant was attributed to both stomatal and mesophyll cell properties (Woledge, 1977). Number of fruits per plant produced under 100 percent PAR (31.2) and 50 percent PAR (30.67) levels were almost similar. These results indicated that tomato can be grown even under 50 percent shade without loosing the number of fruit per plant as compared to open field.

Number of fruit per cluster

Number of fruit per cluster gradually decreased with the decreased of light levels. The highest number of fruit per cluster (3.21) was found under full sunlight (100% PAR) which was followed by 75 percent PAR (3.05), 50 percent PAR (3.01) and 25 percent PAR (2.80) levels.

Fruit diameter

Fruit diameter of tomato grown under different reduced light levels followed almost a similar pattern of variation like number of primary branches per plant, where fruit diameter recorded under full sunlight (48.3 mm) to 50 percent light reduction i.e. 50 percent PAR level (47.10 mm) did not vary significantly. Significantly the lowest fruit diameter was recorded under 25 percent PAR level (40.20 mm). The lower fruit diameter under the heaviest shade level (25% PAR) may be associated with the lower mobilization of reserve assimilates to reproductive organ. Similar findings in case of mungbean was also reported by Ali (1998) and Laosuwan *et al.*, 1992).

Fruit weight

Individual fruit weight also decreased as the light levels decreased. The fruit weight varied insignificantly up to 50 percent light reduction. The maximum fruit weight was observed under 100 percent PAR level (72.79 g) which was closely followed by 75 percent PAR (69.56 g) and 50 percent PAR (68.63 g). Whereas, 25 percent produced significantly the lowest fruit weight PAR (58.66g).

Yield

Tomato yield per plant was also significantly influenced by different light levels (Table 8). The trend of yield per plant was almost similar to that of number of fruit per plant. Among the four light levels, the highest yield per plant was recorded under 75 percent PAR level (2304.47 g) which was statistically identical to that of 100 percent PAR level (2271.32 g) and 50 percent PAR level (2104.88 g). Significantly the lowest yield per plant was found under 25 percent PAR (1365.06 g) level. The highest yield of tomato at 75 percent PAR level may be attributed by the highest number of fruits per plant at 75 percent PAR level. Almost similar result was found by Aidy (1984) who obtained the highest yield of tomato under 40% shade created by artificial nets.

Tomato yield per plant was converted to total yield in ton/ha. The total yield of tomato showed almost similar pattern of variations among the four light levels as tomato yield per plant. Significantly the highest yield was recorded under 75 percent PAR level (96.02 t/ha) which was statistically similar to that of 100 percent PAR (94.62 t/ha) and 50 percent PAR level (87.7 t/ha). Significant the lowest yield was recorded under 25 percent PAR level (56.87 t/ha).

Table 8. Yield and yield contributing characters of tomato at under different light levels

Light level (%PAR)	Number of fruit/ plant	Number of fruit/cluster	Fruit diameter (mm)	Weight /fruit (g)	Yield/ plant (g)	Yield (t/ha)
100	31.20 a	3.21 a	48.30 a	72.79 a	2271.32 a	94.62 a
75	33.13 a	3.05 a	47.44 a	69.56 a	2304.47 a	96.02 a
50	30.67 ab	3.01 a	47.10 a	68.63 a	2104.88 a	87.70 a
25	23.27 b	2.80 a	40.20 b	58.66 b	1365.06 b	56.87 b

Mean followed by a common letter are not significantly different at the 5% level by DMRT.

Relationship between light and yield of tomato

A quadratic polynomial relationship was found between yield of tomato and light (% PAR) which is represented as Y= -0.0129 X^2 + 2.0979 X + 13.12 (R^2 = 0.9131). The R^2 value of this relationship was very high and highly significant (Fig. 5). The R^2 value indicated that about 91 percent of the contribution to the yield of tomato can be explained by the light treatments. This equation also stated that yield of tomato was maximum i.e. 98.407 ton/ha at 81.5 percent PAR level and beyond this PAR, tomato yield decreased at the rate of 0.0129 ton/ha for per unit changing of percent PAR.

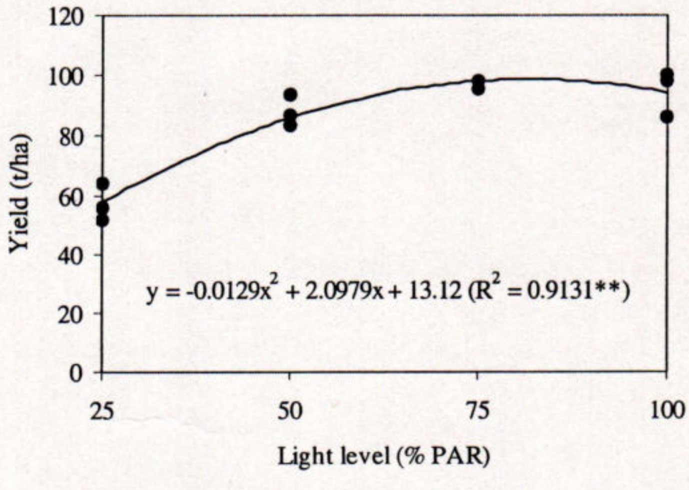

Fig. 5. Relationship between light level (% PAR) and yield of tomato

Performance of Eggplant

Plant height

Plant height is an important morphological character that was influenced by the light levels (Table 9). All the tested varieties of eggplant showed statistically similar height at each light levels, but varied significantly among the different light levels. In general, plant height of all varieties of eggplant increased with the decreased of light levels and the tallest plant was observed under 25 percent PAR irrespective of varieties. This was probably due to higher apical dominance under shade condition (Hillman, 1984). In this light level, Kajla, Uttara and Nayantara varieties scored 103.83 cm, 101.57 cm and 110.42 cm plant height, respectively. These values were statistically similar to the plant height under 50 percent PAR level. The height of Kajla, Uttara and Nayantara under 50 percent PAR were 100.90 cm, 96.57 cm and 99.43 cm, respectively. The shortest plants was observed under 100 percent PAR regardless of varieties (Kajla, Uttara and Nayantara became 77.43 cm, 74.40 cm and 76.78 cm, respectively) which were statistically similar to that of 75 percent PAR. The height of Kajla, Uttara and Nayantara under 75 percent PAR were 86.52 cm, 80.80 cm and 89.83 cm, respectively.

Primary branch

Number of primary branches per plant of all varieties varied significantly under reduced light conditions (Table 10). Among the three varieties of eggplant, Nayantara affected severely by the heaviest shade level, Kajla affected moderately but Uttara was less affected. Among the three varieties, the highest number (5.87) of primary branch was found in Kajla and followed by Uttara (5.73) under full sunlight. Under 75 percent PAR level, Nayantara (5.17) and Uttara (4.85) showed statistically identical number of branches but Kajla showed significantly the lowest number of primary branch. Under 50 percent and 25 percent PAR level all varieties produced statistically similar number of primary branches, each variety influenced differently by different light levels.

In case of Nayantara, number of primary branches increased slightly at 25% reduced light but decreased drastically at 50% reduced light and continued this trend at 75% reduced light also. In case of Kajla, number of primary branches per plant decreased significantly even at 25% reduced light (75% PAR) but further reduction of light levels did not decrease significantly as compared to 25% reduced light. In Uttara variety, number of primary branches did not vary significantly from full light to 50% reduced light levels, but decrease significantly 75% PAR. The lower number of branches under shaded conditions might be due to higher auxin production in plant grown shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al.*, 1999).

Leaf number

Number of leaf per plant of eggplant were significantly influenced by reduced light levels (Table 12). At each light levels, Uttara produced the maximum number of leaf per plant (145.48, 169.17, 158.87 and 113.43 leaf at 100, 75, 50 and 25 percent PAR, respectively) and Nayantara produced the minimum number of leaf (122.93, 129.17, 120.10, and 86.25 leaf per plant under 100, 75, 50 and 25 percent PAR level, respectively).

Among the three eggplant varieties, number of leaf per plant produced at full sun light to 50% reduced light, were not affected significantly, whereas 75% PAR produced the highest number of leaf per plant irrespective of varieties. But number of leaf produced under 25% PAR was significantly lower compared to number of leaf produced under 75% PAR.

Table 9. Plant height of brinjal varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	77.43 a B	86.52 a B	100.90 a A	103.82 a A
Kajla	74.40 a B	80.80 a B	96.57 a A	101.57 a A
Uttara	78.78 a B	89.83 a B	99.43 a A	110.42 a A

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 10. Primary branch per plant of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	5.00 b AB	5.17 a A	3.93 a BC	2.95 a C
Kajla	5.87 a A	4.27 b B	4.33 a B	3.67 a B
Uttara	5.73 a A	4.85 a A	4.67 a A	3.03 a B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 11. Total branches per plant of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	15.20 a A	15.63 b A	13.58 b A	10.08 b B
Kajla	16.87 a A	17.20 a A	17.47 a A	12.40 a B
Uttara	17.98 a A	19.58 a A	18.53 a A	13.33 a B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 12. Leaf per plant of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	122.93 a AB	129.17 b A	120.10 b AB	86.25 a B
Kajla	120.07 a AB	155.27 a A	141.00 a A	99.07 a B
Uttara	145.48 a AB	169.17 a A	158.87 a A	113.43 a B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Number of fruit

Number of fruit per plant of eggplant revealed that Nayantara was the most tolerant variety relatively to other varieties to reduced light levels. Nayantara produced statistically similar number of fruit per plant up to 50 percent reduction of light, but Kajla and Uttara showed similar phenomena up to 25 percent reduction of light (Table 13). However, the potentiality of Nayantara in terms of number of fruit per plant was much lower compared to other two varieties. The variety Uttara produced the highest number of fruit per plant at all light levels followed by Kajla and Nayantara. However all these three varieties produced the highest number of fruit per plant at 100 percent PAR and reduced gradually with the reduction of light levels. Lower number of fruits per plant under relatively more and prolong shaded condition was probably due to poor photosynthetic capacity of plants. The decrease in photosynthetic capacity of shaded plant was attributed to both stomatal and mesophyll cell properties (Woledge, 1977).

Fruit length

Among the three varieties of eggplant the fruit length of Kajla and Uttara affected by the heavy shade level but the fruit length of Nayantara had no affection. Kajla produced significantly the longest fruit than any other of the two varieties at all light levels. Kajla and Uttara produced significantly the shortest fruit under 25 percent PAR level. Nayantara produced statistically similar length of fruit under all light levels.

Fruit diameter

Diameter of fruit of eggplant varieties varied significantly irrespective of varieties and light levels. At each light level, Nayantara produced significantly the highest diameter of fruit and Uttara produced significantly the lowest diameter of fruit. Among the three eggplant varieties, Nayantara produced its maximum fruit diameter under 75% PAR (85% mm), where as Kajla and Uttara produced their maximum diameter of fruit at 100% PAR (40.13 and 34.17 mm). The fruit diameter of Kajla and Uttara gradually decreased with the decreased of light level. Although all varieties of eggplant showed statistically similar diameter of fruit up to 50% reduction of PAR level.

Fruit weight

The weight per fruit of eggplant varieties was significantly varied irrespective of varieties and light levels (Table 16). The fruit weight showed almost similar pattern as found in fruit diameter. At each light levels Nayantara produced significantly the highest fruit weight (223.19 g, 241.83 g, 222.67 g and 186.83 g at 100, 75, 50 and 25 percent PAR, respectively) followed by Kajla (90.72 g, 93.30 g, 96.00 g and 70.63 g was found at 100%, 75%, 50% and 25% PAR, respectively). Uttara produced significantly the lowest weight per fruit at each light level (65.28 g, 66.42 g , 64.40 g and 37.80 g at 100, 75, 50 and 25 percent PAR, respectively). Nayantara and Uttara varieties produced their heaviest fruit at 75 percent PAR which were statistically similar to their fruit of 100 percent PAR and 50 percent PAR. In Kajla heaviest fruit was found under 50 percent PAR but in all varieties fruit weight varied insignificantly up to 50 percent PAR level. All the three varieties produced their smallest fruit, under 25 percent PAR level.

Table 13. Number of fruit per plant of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	6.78 c A	6.00 c A	6.28 b A	4.33 b B
Kajla	16.25 b A	15.30 b AB	14.77 a B	9.18 a C
Uttara	20.40 a A	19.70 a A	15.47 a B	9.20 a C

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 14. Fruit length (cm) of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	9.07 b A	9.00 b A	9.17 b A	7.00 b A
Kajla	14.47 a A	13.50 a A	12.67 a A	10.17 a B
Uttara	10.17 b A	9.83 b A	9.33 b A	6.87 b B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 15. Fruit diameter (mm) of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	81.11 a A	85.00 a A	81.70 a A	72.80 a B
Kajla	40.13 b A	39.50 b A	39.67 b A	34.67 b B
Uttara	34.17 c A	33.83 c A	30.30 c AB	26.47 c B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 16. Weight per fruit (gm) of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	223.19 a A	241.83 a A	222.67 a A	186.83 a B
Kajla	90.72 b AB	93.30 b A	96.00 b A	70.63 b B
Uttara	65.28 c A	66.42 c A	64.40 c A	37.80 c B

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 17. Yield per plant of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	1513.23 a A	1450.98 a A	1398.36 a A	825.78 a B
Kajla	1474.21 a A	1427.49 a A	1417.92 a A	648.38 b B
Uttara	1334.56 b A	1308.47 b A	996.26 b B	347.76 c C

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Table 18. Yield (t/ha) of eggplant varieties under different light levels

Varieties	Light regimes (% PAR)			
	100	75	50	25
Nayantara	50.51 a A	48.18 a A	46.81 a A	27.13 a B
Kajla	49.35 a A	47.80 a A	47.75 a A	21.27 b B
Uttara	44.48 b A	43.61 b A	33.13 b B	11.77 c C

In a column means followed by a small letter and in a row by a capital letter are not significantly different at the 0.05 level by DMRT.

Yield

Yield per plant of eggplant varieties varied significantly by the reduced light level. Eggplant yield per plant was gradually decreased as shade levels increased. Among the three varieties of eggplant, Uttara affected severely by the heavy shade levels, Nayantara affected moderately and Kajla was less affected in respect of yield per plant (Table 17). Nayantara and Kajla produced statistically similar yield up to 50 percent reduction of light level, but Uttara could produce statistically similar yield up to 25% reduction of light level. At 50 percent PAR, yield reduction in Kajla and Nayantara was 3.80 and 7.60 percent, respectively as compared to 100 percent PAR. The result of yield per plant revealed that Kajla was the most tolerant than Nayantara and Uttara in reduced light levels. Uttara produced significantly the lowest yield at each light levels. Similar trend of yield in Indian spinach and Red amaranth was observed by Wadud (1999).

The changing pattern of yield ton per hectare was similar to the yield per plant by the reduced light levels, as the yield per plant was converted into ton/ha. Nayantara produced 50.51, 48.18, 46.81 and 27.13 ton/ha at 100, 75, 50 and 25 percent PAR, respectively, which is followed by Kajla (49.35, 47.8, 47.75 and 21.27 ton/ha at 100, 75, 50 and 25 percent PAR, respectively). Uttara produced significantly the lowest yield at each light level (44.48, 43.61, 33.13 and 11.77 t/ha at 100%, 75%, 50% and 25% PAR, respectively). The highest yield was obtained from Nayantara at 100% PAR followed by Kajla. The lowest yield (11.77 t/ha) was obtained from Uttara at 25 percent PAR level.

Relationship between fresh yield of Eggplant and light

Linear relationships between light (% PAR) and fresh yields of all the three varieties of eggplant were estimated as Y= 0.286 X + 25.28 (R^2 = 0.7316) for Nayantara, Y= 0.3372 X + 20.47 (R^2 = 0.6463) for Kajla and Y = 0.4344 X + 6.095 (R^2 = 0.8488) for Uttara. The R^2 values of the equations for Nayantara, Kajla and Uttara were 0.7316, 0.6463 and 0.8488, respectively, which were high and significant (Fig. 6). The R^2 values indicated that 73.16, 64.63 and 84.88 percent yield of Nayantara, Kajla and Uttara were attributed due to percent PAR. The relationship also stated that the yield of Nayantara, Kajla and Uttara were changed at the rate of 0.29 t/ha, 0.34 t/ha and 0.43 t/ha respectively for per unit of changing of percent PAR.

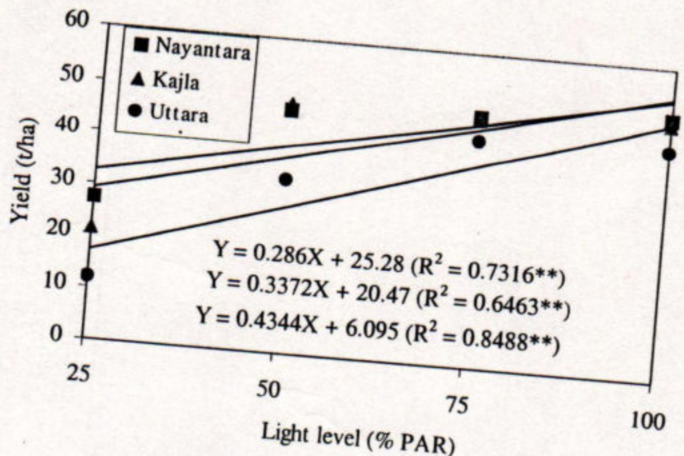

Fig. 6. Relationship between light level (% PAR) and yield of different eggplant varieties

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

SUMMARY

Performances of five winter vegetables were evaluated under different reduced light levels at the research farm of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, during the period from November, 1999 to March, 2000.

The treatments of the experiment were four different lights level i.e., 100, 75, 50 and 25 percent Photosynthetically Active Radiation (PAR). The reduced light levels (i.e., 75, 50 and 25 percent PAR) were created by using mosquito nets of different pore sizes. The four winter vegetables such as cabbage, carrot, radish and tomato were grown side by side following the RCBD design. Eggplant was grown in Split Plot Design. Each treatment was replicated three times.

Performances of five winter vegetables under different light levels are summarized below:

Cabbage

Performance of cabbage in term of morphological behaviour as well as fresh and dry yield was affected significantly by the different light levels. Length of outer leaf of cabbage was increased gradually with the increased of shade levels. The longest leaf (42.00 cm) was found under heavy shade i.e. 25 percent PAR and the shortest leaf (37.28 cm) was recorded at full sunlight i.e. 100 percent PAR. Leaf breadth of cabbage was increased significantly as the light level decreased up to a certain light level i.e. 50% PAR. Further decreased of light levels, leaf breadth decreased drastically. Significantly the highest number of outer leaf per plant (17.63) was observed under 25 percent PAR which was followed by 100 percent PAR (16.61) and 75 percent PAR (15.95). Significantly the lowest number of outer leaf per plant (14.42) was recorded under 50 percent PAR. The highest outer leaf fresh weight per plant (739.69 g) was recorded under 75 percent PAR which was statistically identical to those of 100 percent PAR (663.34 g) and 50 percent PAR (680.76 g). Significantly the lowest leaf fresh weight per plant (436.18 g) was recorded under 25 percent PAR. Outer leaf dry weight per plant showed the similar trend to the outer leaf fresh weight per plant. The length of head gradually increased up to 50 percent reduced light level. With the further increased of shade level (decreased of PAR levels), head length significantly decreased. In cabbage, minimum head breadth (9.76 cm) was found under maximum shade (25% PAR). But head breadth under any of the other three treatments i,e., 50 (15.29 cm), 75 (15.25 cm) and 100 percent PAR (15.13 cm) did not vary statistically. Head fresh weight progressively increased up to 50 percent reduction of light levels. With the further increased of shade level (decreased of

PAR levels), head length decreased drastically. The head dry weight per plant showed similar trend to the head fresh weight per plant. The relationship between fresh yield of cabbage and light (% PAR) showed a quadratic polynomial equation as $Y = -0.0072 X^2 + 1.0961 X - 9.4575$ ($R^2 = 0.9269$), where R^2 value was high and highly significant. This equation also stated that the yield of cabbage was maximum i.e. 32.26 ton/ha at 76 percent PAR level, and beyond this PAR level (76%) cabbage yield decreased at the rate of 0.0072 t/ha for per unit changing of percent PAR.

Carrot

In carrot, two parameters i.e. plant height and leaf length were increased with the light levels decreased but the other parameters showed superior performance under 25 percent reduced light levels (75% PAR). In case of plant height and leaf length, significantly the highest values were observed under 25% PAR level and the lowest values were recorded under full sunlight. In case of length of carrot, the highest value was observed under 75 percent PAR, which was statistical similar to 50 percent PAR level. Significantly the highest yield of carrot (30.64 ton/ha) was obtained under 75 percent PAR (25% reduced light) which was significantly higher than both the yield recorded under full sun light and 50 percent PAR. The yield under 100 percent PAR (26.98 ton/ha) was statistical identical to the yield observed under 50 percent PAR (27.25 ton/ha). The results suggest that carrot can be grown successfully under 25-50 percent reduced light conditions in agroforestry systems.

A quadratic polynomial relationship was found between yield of carrot and light (% PAR) which was represented as $Y=-0.0068X^2 +1.0138X -6.9267$ ($R^2 =0.9697$), where the R^2 value very high and highly significant. The R^2 value indicated that 96.97 percent of the contribution to the yield of carrot could be explained by percent PAR. This equation also state that yield of carrot was maximum i.e. 30.8583 t/ha. at 75 percent PAR level.

Radish

The growth characters and yield contributing characters of radish were influenced significantly by the different light levels. The maximum number of leaf per plant (18.54) was recorded under 75 percent PAR which was statistically similar to that of 100 percent PAR and 50 percent PAR levels. The lowest number of leaf per plant (14.64) was found under 25 percent PAR. The longest leaf was found under 25 percent PAR (43.56 cm) which was statistically similar to that of 50 percent PAR (42.56 cm). The leaf breadth of radish was increased gradually as the light levels decreased or shade level increased. Significant the lowest leaf dry weight (5.42 g) was observed under 100 percent PAR. The leaf dry weight produced under 75 percent PAR (7.79 g) was significantly the highest which was statistically similar to that of 50 percent PAR (7.54 g) and 25 percent PAR (7.39g). The highest radish length (16.25 cm) was obtained under 75 percent PAR which was followed by 100 percent PAR (14.89 cm) and 50 percent PAR (14.20 cm). Significantly the shortest radish (12.9 cm) was found under 25% PAR. The maximum girth value of radish was recorded under 75 percent PAR which was identical to the value obtained at 100 percent PAR (12.05 cm). Reduction of light levels from 75 percent to 25 percent PAR had decreased the radish girth significantly. The highest radish yield per plant (152.33 g) was found under 75 percent PAR. At 100 percent PAR, the radish yield was 135.75 gm/plant, which was statistically higher than that of 50 percent PAR (110.46 g). The total yield of radish in ton/ha, followed similar pattern of variations as yield/ plant.

The relationship between fresh yield of radish and light levels (% PAR) showed a quadratic polynomial equation as $Y = -0.0083 X^2 + 1.3395 X -20.998$ ($R^2 = 0.9964$), where the R^2 value was high and highly significant. This equation also stated that yield of radish was maximum i.e. 33.05 ton/ha at 81 percent PAR level, and beyond this PAR level (81%) radish yield decreased at the rate of 0.0083 ton/ha for per unit changing of percent PAR.

Tomato

Tomato plant cultivated under shade grew more vigorously than those grew in the open field. With the increased shade levels (decreased of PAR levels), plant yield per plant was recorded under 75 percent PAR (2304.47 g) which was statistically identical to that of 100 percent PAR (2271.32 g) and 50 percent PAR (2104.88 g). Significantly the lowest yield per plant was found under 25 percent PAR (1365.06 g).

A quadratic polynomial relationship was found between yield of tomato and light (% PAR) which was represented as $Y = -0.0129 X^2 + 2.0978 X + 13.122$ ($R^2 = 0.9919$). The R^2 value of this relationship was very high and highly significant (Fig. 4). The R^2 value indicated that 99.19 percent of the contribution to the yield of tomato can be explained by the light treatments. This equation also stated that yield of tomato was maximum i.e. 98.407 ton/ha at 81.5 percent PAR level and beyond this PAR tomato yield decreased at the rate of 0.0129 ton/ha for per unit changing of percent PAR.

Eggplant

All the three tested varieties of eggplant showed statistically similar plant height at each light levels, but varied significantly among the different light levels. In general, plant height of all varieties of eggplant increased with the decreased light levels and the tallest plant was observed under 25% PAR irrespective of varieties. Number of primary branches per plant of all varieties varied significantly under reduced light conditions. Among the three varieties of eggplant, Nayantara affected severely by heavy shade level, Kajla affected moderately but Uttara was less affected. In case of leaf per plant, the highest number of leaf per plant of eggplant were found under 75 percent PAR level regardless of varieties. However, Uttara produced the maximum number of leaf per plant at each light level (145.48, 169.17, 158.87 and 113.43 leaf at 100, 75, 50 and 25 percent PAR, respectively) and Nayantara produced the minimum number of leaf per plant at each light level. Number of fruit per plant of eggplant revealed that Nayantara was the most tolerant variety relatively to other varieties at reduced light levels. Nayantara produced statistically similar number of fruit per plant up to 50 percent reduction of light, but Kajla and Uttara showed similar phenomena up to 25 percent reduction of light. The variety Uttara produced the highest number of fruit per plant at all light levels followed by Kajla and Nayantara. However all these three varieties produced the highest number of fruit per plant at 100 percent PAR and reduced gradually with the reduction of light levels. The highest yield (ton per ha) of all varieties of eggplant were found at 100 percent PAR. The yield of all three varieties gradually decreased with decreased of light levels. The yield of Nayantara, Kajla and Uttara at 100 percent, 75 percent, 50 percent and 25 percent PAR level were 50.51, 49.35, 44.48, 48.18, 47.8, 43.6; 46.81, 47.75, 33.13 and 27.13, 21.27, 11.77 t/ha, respectively. The results indicated that Kajla was the most shade tolerant followed by Nayantara upto 50 percent reduced light levels, based on yield performance, Uttara was the less tolerant to shade among the three varieties of eggplant.

Linear relationships between light (% PAR) and fresh yields of all the three varieties of eggplant were estimated as Y= 0.286 X + 25.28 (R^2 = 0.7316) for Nayantara, Y= 0.3372 X + 20.47 (R^2 = 0.6463) for Kajla and Y = 0.4344 X + 6.095 (R^2 = 0.8488) for Uttara. The R^2 values of these equations for Nayantara, Kajla and Uttara were 0.7316, 0.6463 and 0.8488, respectively, which were significant. The R^2 values indicated that 73.16, 64.63 and 84.88 percent yield of Nayantara, Kajla and Uttara were attributed due to percent PAR. The relationship also stated that the yield of Nayantara, Kajla and Uttara were changed at the rate of 0.29 t/ha, 0.34 t/ha and 0.43 t/ha, respectively, for per unit of changing of percent PAR.

CONCLUSION AND RECOMMENDATIONS

The results of the present studies revealed that performances of the different winter vegetables grown under different light levels were different. Among the five different types of winter vegetables, yields of the all vegetables except eggplant were maximum under partial shade conditions, whereas eggplant grown under full sunlight gave relatively higher yield than those of the other reduced light treatments. Cabbage and tomato produced the highest yields under 50 and 75 percent PAR, respectively, though variations in yields from full sunlight to 50 percent PAR in both vegetables were statistical similar. Carrot and radish produced significantly the higher yields under 75 percent PAR. However, the yield of carrot under 50 percent PAR was even numerically higher than that of 100 percent PAR, but in radish, yield under 50 percent PAR was significantly lower than that of 100 percent PAR. Though eggplant (irrespective of varieties) produced higher yield at full sunlight, but Nayantara and Kajla can be grown up to 50 percent reduced light levels and Uttara can be grown up to 25 percent reduced light level without significantly yield loss.

Between yield of vegetables and light levels, linear relationships were found in eggplant, whereas, quadratic polynomial relationships were observed in cabbage, carrot, radish and tomato. Using the linear equation, it was showed that yield of eggplant decreased as the light level decreased, but eggplant varieties i.e.

Nayantara, Kajla and Uttara can be grown up to at 80, 79 and 85 percent PAR levels, respectively, without significant yield loss. But the quadratic polynomial equations stated that yields of cabbage, carrot, radish and tomato were maximum at 76, 75, 81 and 82 percent PAR, respectively.

Therefore, it may be concluded that all the tested winter vegetables are suitable in agroforestry systems, but degree of their suitability may be ranked as cabbage > carrot > tomato > radish > eggplant (Kajla/Nayantara>Uttara).

However, the results of the present studies were achieved based on one season trial which may not be sufficient to asses the sustainability of the results. So, similar experiments should be repeated at least in another season so that results would be conclusive. On the other hand, the findings of these studies were obtained based on different reduced light levels created in an artificial condition, but the light or shade conditions in the understorey canopy of the agroforestry systems may not be exactly similar. Therefore, the final results of the study should be validated in agroforestry situations to identify the adoption domain of the techniques as revealed in the present study.

CHAPTER VI

LITERATURE CITED

Abedin, M. Z. and M. A. Quddus, 1990. Homestead fuel situation, homegardens and agroforestry practices at six-agroecologically different locations of Bangladesh. *In:* Abedin *et. al,* (ed). Homestead plantation and agroforestry in Bangladesh. BARI, Winrock International and BARC. pp 19-53.

Ahmed, A. Begum, A.R., Hoque, M. 1983. A comparative study on the growth and yield of fifteen cultivars of Eggplant grown in the grey flood plain soils of Jamalpur. Bangladesh horticulture. Vol. 11. No. 2 pp. 15-20.

Aidy, F.EL. 1984. Research on the use of plastics and shade nets on the production of some vegetable crops in Egypt. Faculty of Agriculture, Kafr EL-Sheikh, Egypt, Acta-Horticulture, No. 154, 109-113; 7 ref.

Akbar, G., M. Rafique, Ahmad and K.N. Babar. 1990. Effect of trees on the yeild of wheat crops. Agroforestry system 11:1-10.

Akter, M. S., M. Z. Abedin and M. A. Quddus. 1989. Why farmers grow trees in agricultural fields: some thoughts, some results. In: Research Report,1988-89. On Farm Research Division, Joydebpur.

Ali, M. A. 1999. Performance of Red amaranth and Lady's finger growth at different orientations and distances under Guava and Drumstick trees. MS. Thesis. BSMRAU, Gazipur, Bangladesh.

Ali, M.A. 1998. Growth and yield of mungbean genotype under sun and shade conditions. Unpublished MS Thesis, BSMRAU, Bangladesh.

Anonymous, 1983. A booklet on Gimakalmi- Anew summer vegetable (Bengali), Citrus and Vegetable Seed Research Center,BARI, Joydebpur, Gazipur.

Anonymous, 1989. Annual Weather Report, IPSA, Meteorological Station, IPSA, Salna, Gazipur. p.2.

Anonymous. 1998. Year book of Agricultural Statistics of Bangladesh Bureau of Statistics. P.

BBS (1996). Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics. Ministry of Planing, Government of the Peoples Republic of Bangladesh, Dhaka, Bangladesh.

BBS (1998). Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics. Ministry of Planing, Government of the Peoples Republic of Bangladesh, Dhaka, Bangladesh.

Chatfield, C. 1949. Food composition Tables for International Use, F.A.O. Nutritional Studies No. 3, Washington.

Chatfield, C. 1954. Food Composition Tables, Minerals and Vitamins for International Use, F.A.O. Nutritional studies No. 11, Rome.

Chaturvedi, G. S. and K. T. Ingram. 1989. Growth and of low land rice in response to shade and drainage. Philippine J. of Crop Science. 14(2):61-67.

Ali, M.A. 1998. Growth and yield of mungbean genotype under sun and shade conditions. Unpublished MS Thesis, BSMRAU, Bangladesh.

Anonymous, 1983. A booklet on Gimakalmi- Anew summer vegetable (Bengali), Citrus and Vegetable Seed Research Center,BARI, Joydebpur, Gazipur.

Anonymous, 1989. Annual Weather Report, IPSA, Meteorological Station, IPSA, Salna, Gazipur. p.2.

Anonymous. 1998. Year book of Agricultural Statistics of Bangladesh Bureau of Statistics. P.

BBS (1996). Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics. Ministry of Planing, Government of the Peoples Republic of Bangladesh, Dhaka, Bangladesh.

BBS (1998). Statistical Year Book of Bangladesh, Bangladesh Bureau of Statistics. Ministry of Planing, Government of the Peoples Republic of Bangladesh, Dhaka, Bangladesh.

Chatfield, C. 1949. Food composition Tables for International Use, F.A.O. Nutritional Studies No. 3, Washington.

Chatfield, C. 1954. Food Composition Tables, Minerals and Vitamins for International Use, F.A.O. Nutritional studies No. 11, Rome.

Chaturvedi, G. S. and K. T. Ingram. 1989. Growth and of low land rice in response to shade and drainage. Philippine J. of Crop Science. 14(2):61-67.

Chauhan, V.V.S. 1989. Cole Crops, vegetable production in India. Agra, India, pp. 117-147.

Choudhury, B. 1962. Eggplant varieties and their cultivation operations, vegetable supplementary, Ind. Farm. 12(6), pp. 34-40.

Chowdhury, B. 1979. Vegetables. National Book Trust, New Delhi, India. p. 88.

Chowdhury, M.K. and M.A. Satter. 1993. Homestead and crop land agroforestry practices in the high Ganges river Floodplain. pp. 23-56. In: Agroforestry Farming System Linkage in Bangladesh. BARC Winrock International. Dhaka, Bangladesh.

Crookston, R.K., K.J. Treharne, P. Ludford and J.I. Ozbun. 1975. Response of beans to shading. Crop Sci. 15: 412-416.

Haque, M. A. 1988. Agroforestry in Bangladesh : Production of trees and crops. Seminar presented at the 26th National Agroforestry Working Meeting held on 25 November 1996. BARC, Dhaka, Bangladesh.

Harou, 1983. Economic principles of appraise agroforestry project. Agricultural Administration. 12 : 127-139.

Hegde, N. G. and K.G. MacDicken, 1990. Orienting multipurpose tree species research to small farm needs. In : Proceedings on Multipurpose tree Species Research for small Farms : Strategies and methods, held on November 20-23, 1989 in Jakarta, Indonesia.

Hillman, J. R. (1984). Apical dominance, In : Wilking, M. b. (ed.) Advanced Plant Physiology. Pitman, London, PP. 127-148.

Hillman, J. R. Math, V. B. and Medlow, G. C. (1977). Apical dominance and the levels of indole acetic acid in *Phaseolus* lateral buds Planta 134, 191-193.

Hocking, D. and K. Islam. 1998. Trees on farms in Bangladesh Growth of top and root pruned trees in Woodland rice fields and yields of under story crops. Agroforestry system 39: 101-115.

Hossain, M. K. 1999. Shade effects on the yield and quality of Pineapple in a jackfruit - pineapple agroforestry system. MS thesis, BSMRAU, Gazipur, Bangladesh.

Hossain. S. F. 1996. A comparative study on yield and quality of some amaranth genotypes (*Amaranthus tricolor* L.), An MS thesis, Institute of Post Graduate Studies in Agriculture, Salna, Gazipur, Bangladesh.

Howard, S.B., C. K. Ong, M. R. Rao, M. Mathuva and C. R. Black. 1995. The partitioning of light and water in *Leucaena*- maize agroforestry systems. *In:* Sinoquet, H. and P. Cruz (ed) Ecophysiology of tropical intercropping IRNA, Edition, Paris, France.

Islam, M. S. and M. A. Haque. 1992. Soil and fertilizer for vegetables. In : Vegetable production and marketing. Proceeding of a national review of planning workshop. 26-29 July 1992, BARI, Joydebpur, Gazipur, Bangladesh. pp 116-129.

Islam, S.M. 1995. Effect of shading on gas exchange characteristics and productivity of mungbean and blackgram. Unpublished MS Thesis, BSMRAU, Bangladesh.

Itai, C. and Birnbaum, H (1991) Synthasis of plant growth regulators by roots. In: Waisel, and Kafkafi, U. (eds) Plant Roots the Hidden Half. Marcel Dekker, New York, pp. 163-178.

Jackson, J, E. 1987. Tree and crop selection and management to optimize overall system productivity especially light utilization in agroforestry. Meteorology and Agroforestry. ICRAF, WHO and UNEF.

Jadhav, B. B. 1987. Effect of partial shading on the yield or rice. Indian J. of Agric. Sci. 57(7) :193-205.

King, K. F. S. 1979. Some principles of agroforestry. Key note address delivered at the National Seminar on Agroforestry in India, May 16-18, 1979. Shillong.

MacDicken, K.G. and N. Vergara. 1990. (eds). Agroforestry: Classification and Management. John Willey, New York, USA.

Miah, M. G. 1993. Performance of selected multipurpose tree species and field crops grown in association as affected by tree branch pruning. A Ph. D. dissertation. CLSU, Philippines.

Miah, M. G., D. P. Garrity and M.L. Argon. 1995. Light availability to the understorey annual crops in an agroforestry system. *In* : Sinoquet, H. and P. Cruz (ed) Ecophysiology of tropical inter cropping. IRNA Editions, Paris, France.

Miah, M.G., Rahman, M.A. and Haque, M.M. 1999. Performance of onion under different reduced light levels for agroforestry and intercroping systems. Bulletin of Tropical Agriculture, 22 (In press).

Murshed, A.N.M.M. 1996. Influence of management conditions on growth, flowering and pod set, seed development and yield of chickpea. Unpublished M.S. Thesis, IPSA, Bangladesh.

Muthukrishnan, C. R. and I. Irulappan, 1986. Amaranthus In : Bose, T. K. and M. G. Som (ed). Vegetable crops in India. Naya Prokash, Calcutta- six, India.

Nadkarni, K.M. 1927. Indian Meteria Medica, Published by Nadkarni & Co., Bombay.

Nair, P. K. R. 1980. Agroforestry species. *In* : Crop Sheets Manual. ICRAF, Nairobi, Kenya.

Nair, P. K. R. 1983. Agroforestry System in the Tropics. Kluwer Academic Publishers / ICRAF.

Nair, P. K. R. 1990. An Introduction to Agroforestry. Kluwer Academic Publishers, ICRAF.

Nayak, S.K. and K.S. Murty. 1980. Effect varying light intensities on yield and growth parameters in rice. Indian J. Plant Physiology. 23: 309-316.

Okigbo, B.N. 1980. The importance of mixed stands in tropicalagriculture.In:R.G. Hurd, P.V. Bisco and C. Dennis (eds), Opportunity for increasing crop yields. Boston, London and Melbourne: Pitman.

Okigbo, B.N. and D.J. Greenland. 1976. Inter cropping systems in tropical Africa. Multiple cropping. American Society of Agriculture. Publication No. 27.

Ong, C.K. 1988. The interaction light, water and nutrients in agroforestry system. Chapter for book on "Application of Biological Research on Asian Agroforestry" J.A. 885.

Ong, C.K., J.E. Corlett, R.P. Singh and C.R.Black. 1991. Above and below ground interactions in agroforestry systems. Forest Ecology and Management, 45:45-57.

Ong, C.K., M.R. Rao, and M. Mathuva. 1992. Trees and Crops: Competition for resources above and below ground. Agroforestry Today, 4(2): 4-5.

Park, H. and H.G. Kwon. 1975. Effect of shading and air temperature on the productivity of Jinheung and IR 667 rice. J. Kor. Soc. Soil Sci. Fert. 8(4): 183-188.

Park, S.K., Y.S.Kwon, Y.B.Lee, and C.I.Lim. 1982. Effect of shading and a fog mist system on the growth of three vegetable crops in a plastic house during the summer. Research reports, 24:12, 106-116; 30 ref.

PCARRD. 1983. Technology for agroforestry. Agroforestry in Perspective: Proceeding of Agroforestry Symposium Workshop, December 19-20, 1979. PCARRD, Los Banos.

Purohit, M.L. 1984. Consolidation of holdings, land tenure related problems in agroforestry. Agroforestry in Arid and semi-Arid Zones. Central Arid Zone Research Institute India.

Rabarimandimby, B.A.1992. Productivity and sustainability of upland rice-mungbean cropping system using *Desmanthus virgates*hedgrows. A Ph. D. dissertation, UPLB.

Rachie, K.O. 1983. Intercropping tree legume with annual crops. Plant Research and Agroforestry. ICRAF.

Rang, A., M.L. Bhat, A.S. Makaya, N. A. Masoodi, A.Z. Anani and D.P. Sharma. 1990. Cited in Solanki, K.R. Agroforestry Research in India. Indian Journal of Agricultural Science. 68 (8, Special issue): 559-66, 1998.

Rashid, M.M. 1976. `Bangladesher Sabji'. Bangla Academy, Dhaka, Bangladesh. pp. 234-259.

Reifsnyder, W.E. 1987. Control of solar radiation in agroforestry practices. Meteorology and Agroforestry. ICRAF, WHO and UNEP.

Saxena, M.B.L. 1984. Improved crop variety in agroforestry. Agroforestry in Arid and semi-Arid Zones. Central Arid Zone Research Institute, Jodhpur India.

Schoch, P.G. 1972. Effects of shading on structural characteristics of the leaf and yield fruit in *Capsicum annul* L. J. Amer. Soc. Hort. Sci. 97(4):461-464.

Shinohara, S. 1978. Production and prospect of short period leafy vegetables of south-east Asian during rainy season in Bangladesh. Central Extension Resources Development Institute (CERDI), Joydebpur, Dhaka, Bangladesh. pp. 36-38.

Singh, R. P., C.K. Ong and W. Sharma, 1989. Above and below ground interactions in alley cropping in semi-arid India. Agroforestry system. 9:259-274.

Solanki, K.R. 1988. Agroforestry Research in India. Indian Journal of Agricultural Sciences 68 (8, special issue): 559-66.

Vergara, N.T. 1982. New directions in agroforestry: the potentials of tropical legume trees. EAPI, East-west center Honolulu, Hawaii.

Wainwright, J. 1995. Towards a coupled light partitioning and transpiration model for use in intercrops and agroforestry. In: Sinoquet, H. and P. Cruz (ed) Echophysiology of tropical intercropping. IRNA Editions, Paris, France.

Wallace, J.S.1995. Towards a coupled light partitioning and transpiration model for use in intercrops and agroforestry. In: Sinoquet, H. and P.Cruz (ed) Ecophysiology of tropical intercropping. INRA Editions, Paris, France.

Watt, R.L. and Merril, 1964. Composition of Foods. Raw, Processed, prepared, Agriculture Handbook No. 8, U.S.A. Deptt. Agriculture, Washington.

Willey, R.W. 1979. Intercropping- its importance and research needs. 1. Competition and yield advantages and 2. Agronomy and research approaches. Field Crop Abstract, 32: 1-10, 73-85.

Willey, R.W, M. Natararyan, M.S. Reddy and M.R. Rao. 1986. Cropping systems with groundnut: Resource use and productivity . In: Agrometeorology of groundnut. Proceeding of an International Symposium, 21-26 August, 1985. ICRiSAT, Sahelian Centrer, Niamey, Niger 193-205.

Wolff, X.Y. and R.R. Coltman. 1990. Productivity of eight leafy vegetable crops grown under shade in Hawaii. Journal of the American Society for Horticultural Science, 115:1, 182-188: 18 ref.

Yamoah, C.F., A.A. Agboola and K.Molongay. 1986. Decomposition, nitrogen release and weed control by pruning of selected alley cropping shrubs. Agroforestry Systems, 4: 239-246.

Yoshida, S. and F.T. Parao. 1976. Clinatic influence on yield and yield components of lowland rice in the tropics. In: Clinatic and Rice, IRRI. Los Banos, Philippines: 471-496.