PERFORMANCE OF SUMMER VEGETABLES UNDER REDUCED LIGHT CONDITION AS AGROFORESTRY SYSTEMS

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CERTIFICATE

*This is to certify that the thesis entitled **'PERFORMANCE OF SUMMER VEGETABLES UNDER REDUCED LIGHT CONDITION AS AGROFORESTRY SYSTEMS'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science (MS)** in **Agroforestry & Environmental Science**, embodies the results of a piece of bonafide research work carried out by **Sazedatur Rahman**, Registration number: **09-03376,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: December, 2014
Place: Dhaka, Bangladesh

Dr. Nazmun Naher
Professor
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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PERFORMANCE OF SUMMER VEGETABLES UNDER REDUCED LIGHT CONDITION AS AGROFORESTRY SYSTEMS

ABSTRACT

A field experiment was conducted at Central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from March, 2014 to June, 2014. The aim of the study was to select best summer vegetables, suitable for inclusion under shade condition in agroforestry systems. The selected vegetables were also grown in control i.e., open field condition. The vegetables were Indian Spinach, Stem Amaranth, Kangkong, Okra, Eggplant and Chilli and treatments were (a) T_{sun} = planting summer vegetables under full sunlight and (b) T_{shade} = planting summer vegetables under shade condition (reduced light intensity). The experiment was laid out following single factor RCBD design. Three replications were used for each treatment for each crop. During the study period maximum light intensity reduction was recorded in Chilli (42.2%) and minimum light intensity was reduced in case of Indian Spinach (22%) under shade. The shade had substantial effects on various growth parameters of the summer vegetables. From the experiment, significant result was observed in all morphological characteristics for all vegetables except Chilli under reduced light. Apart from this, highest yield was found in Kangkong (18.67 ton/ha) and Okra (22.54 ton/ha) in reduced light condition. Highest yield of Indian Spinach (8.93 ton/ha), Stem Amaranth (27.67 ton/ha), Eggplant (22.63 ton/ha) and Chilli (8.06 ton/ha) was recorded under full sunlight. Considering shade condition, Kangkong and Okra were best suitable for growing in Agroforestry systems.

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LIST OF ABBREVIATIONS AND ACRONYMS

FULL WORD	ABBREVIATION
And others (at elli)	*et al*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh Forest Department	BFD
Centimeter	cm
Degree of Freedom	df
Degree Celsius	˚C
Diameter	diam
ed est (means That is)	i.e.
Exempli gratia (by way of example)	e.g.
Food and Agriculture Organization	FAO
Gross Domestic Product	GDP
Gram	g
Hectare	Ha
Kilogram	Kg
Least significant difference	LSD
Million hectare	Mha
Millimeter	mm
Photosynthetically Active Radiation	PAR
Percentage	%
Randomized Complete Block Design	RCBD
Metric, 1000 kg	Ton

CHAPTER I

INTRODUCTION

Bangladesh is one of the most densely populated countries of the world struggling hard to feed her 15.47 crore people (BBS, 2015). If the current population growth rate (1.37%) continues, population will be increased to 180 million by the year 2025, and the country will face enormous problems to nurse her population. The economy of the country draws its strength and stability mostly from agriculture sector for about 16.33% of GDP (Fiscal Year 2013-2014). About 80% of the total population live in rural areas and are directly dependent on agriculture for their livelihood. The country has only a land area of 14.39 million hectares, but due to the ever growing population, per capita land area is decreasing at an average rate of 0.05 ha/cap/year since 1989 (Hossain and Bari, 1996) and therefore steadily declining the land: man ratio.

Like agriculture, forest is declining also with increasing population. A country needs 25% of forest land of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is endowed with only 17% (BFD, 2011) of unevenly distributed forests.

The per capita consumption of vegetable in Bangladesh is only 53 g, which is pretty below the recommended daily requirement of 200 g/head/day. The low consumption of vegetables creates a tremendous pressure over cereals and also causes malnutrition leading to several kinds of health hazards. Vegetables are not produced evenly throughout the year in Bangladesh. About 35% of the vegetables are produced in summer season and the rest in the winter season (Rashid, 1999). Cloudy sky, low light intensity and excess rainfall are the major problems for vegetable production in summer season. The development or identification of high productive summer vegetables could be one of the achievable attempts to solve such problems. On the other hand, there is little scope to increase cultivation area. Hence we need to find out other alternatives.

Agroforestry, the integration of tree and crop/vegetables on the same area of land is a promising production system for maximizing yield (Nair, 1990) and maintaining friendly environment. Understorey crops (include vegetables) can be integrated with forestry, orchard, or other agroforestry systems. But farmers face problems of growing crops after 4-5 years of tree plantations and even sometimes fail to grow understorey crops under and around trees because in agroforestry systems, among different production limitations, light availability may be the most important limitation to the performance of the understory crops/vegetables particularly where an upperstorey perennial forms a continuous overstorey canopy (Miah *et al.*, 1995). However, under a given site condition, light availability to the understory crops/vegetables is dependent on the trees characteristics such as crown shape and density, size of the tree and tree management practices.

In Bangladesh, most of the vegetables grow in winter. Among the very few summer vegetables Indian Spinach, Data, Kangkong, Okra, Eggplant, Chilli are very common. But unfortunately very few studies have been found in relation to screening out different summer vegetables in terms of their adaptability and yield under shade created by the upperstorey trees. In this situation, the present study of interaction performance of six summer vegetables under reduced light level will be a pioneer study to introduce higher yielding and partial shade tolerant summer vegetables. The specific objectives of the study were:

1. To evaluate the yield and yield contributing characters of six summer vegetables under reduced light intensity;
2. To find out the relationship between light and yield of summer vegetables; and
3. To identify the most suitable and adaptive summer vegetable species for agroforestry systems.

CHAPTER II
REVIEW OF LITERATURE

This research has been undertaken to screening of some summer leafy and fruit vegetables under shade. Summer vegetables like Indian Spinach, Danta (Stem amaranth), Kangkong, Okra, Eggplant, Chilli etc. are grown throughout the world and their performance is largely affected under agroforestry system because of inappropriate sunlight. Therefore, literatures related to the performance of crops in tree-crop agroforestry system and characteristics of tree species which were collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented in this chapter under the following headings-

2.1 Concept of Agroforestry

Recently International Centre for Research in Agroforestry (ICRAF) defined, “Agroforestry as a dynamic, ecologically based natural resources management system that through the integration of trees on farmland and in the agricultural landscape, diversifies and sustains production or increased social, economic and environmental benefits for land users at all levels (World Agroforestry Centre, 2006).”

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 intercropping to maximize and sustain agricultural production."

According to Nair (1983) agroforestry is a collective name for all land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial mixture or in temporal sequence.

From a bio-economic point of view, Harou (1983) stated that agroforestry is a combined agriculture-tree-crop farming system which enables a farmer 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, Saxena (1984) reported that agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously. Agroforestry utilizes the inter space tree rows for intercropping with agricultural crops this does not impair the growth and development of the trees but enables farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

Agroforestry combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy and sustainable land-use systems. Small scale agriculture plays an important role in Bangladesh economy. It provides nearly 50% of cash flow to the rural poor (Leuscher and Khaleque, 1987).

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.

MacDicken and Vergara (1990) stated that agroforestry is 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.

Bhatia and Singh (1994) observed that the agroforestry in India plays an important role in increasing biomass production, maintaining soil fertility, conserving and improving soil and averting risk.

Groot and Soumare (1995) observed that decomposition of tree roots and dice substances of the root exudes greatly enhance soil organic matter and thereby soil-fertility. Tree lateral roots may reduce loss of nutrients from the soil by recycling them that would have been otherwise leached from the system. Taproots may take up nutrients, which are released by weathering from deeper soil layers.

Solanki (1998) found that 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 economics goods (fuel, fodder, small timber, organic fertilizer etc) and (iii) providing stable employment, improved income and basic material to rural populations.

2.2 Tree-crop Agroforestry Systems and its Structure

Tree-crop agroforestry or agrisilviculture implies cultivation of agricultural crops in conjunction with forestry crops over the same unit of land to maximize productivity and sustainability of the land.

Akter *et al.*, (1989) mentioned that farmers also considered tree as savings and insurance against risk of crop failure and low yield, as well as assets for their children. Some farmers stated that tree would contribute towards expenses for marriage of their daughters. In tree crop agroforestry system tree species are grown and managed in the farmland along with agricultural crops. The aim is to increase the overall yield of the land. This system is also based on the principle of sustained yield (Nair, 1990).

According to Miah *et al.*, (1995) Agroforestry system is a system that incorporates a range of tree and crop species offers much more scope for useful management of light interception and distribution than monoculture forests and agricultural crops.

2.3 Performance of Crops in Agroforestry Systems

The performance 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, compatibility; between tree lines, management practices, soil and climatic factors.

Muthukrishnan and Irulappan (1986) studied the variability of 95 accessions of *Abelmoschus esculentus* and *Abelmoschus manihot* and he found that significant differences among the accession for all the characters studied viz. plant height, plant spread, number of primary branches per plant, days to flowering, nodes when the first flower appear, number of leaves per plant, leaf length, leaf breadth, petiole length, number of pod per plant, pod weight and total yield variability were greatest.

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

Primak and Shelepora (1989) carried out an experiment in tomato plants grown under a low light intensity and found that there was a marked decrease in the photosynthetic surface area of chloroplasts and a reduction in chloroplast numbers per unit area in the cotyledons of varieties with high light requirements compared with cotyledons from plants of the same varieties a high light intensity. In shade tolerant varieties these difference were less marked.

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

Cockshull *et al*., (1992) carried out an experiment fewer than two shade treatments (light shade and heavy shade) in tomato plants and reported that both two-shade treatments reduced the total fresh weight yield of fruit by 7.5 and 19.95% and the estimated total above ground biomass by 6.2 and 16.5% respectively. Shading reduced average fruit size and also reduces the proportion of fruit in the larger size grades. Heavy shade also reduced the incidence of uneven ripening in summer.

Nasiruddin *et al.*, (1995) conducted an experiment in two cultivars of tomato under different shading condition and reported that shading increased plant height, the tallest plants were those of Marglobe (157.82 cm) in complete shade treatment (black polythene shade) and the shortest was Rama VF controls (83.38 cm) in natural light (no shade). The number of fruit per plants decreases with the increase of shading. But fruit size was greatest and colour was brightest under partial shade (coconut leaves shade). Shading decreased yields of Rama VF and Marglobe from 2.593 and 2.383 kg/m^2 in controls to 2.303 and 2.114 kg/m^2 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 more in pruned conditions (13 kg/ha) than in unpruned conditions (9 kg/ha).

Leonardo (1996) reported that shading (60% light reduction) reduced vegetative and fruit growth. Shading increased plant height shading also reduced chlorophyll content. Stomata density, transpiration rate and photosynthesis rate, yield of peppers decreased with increasing amount of shade levels.

Healey *et al.,* (1998) reported that level of incident radiation reduced by 25% under shade-cloth decreased final yield and final leaf index, but increased canopy leaf, nitrogen concentration and radiation uses efficiency. A similar level of reduced incident radiation under solar weave shade-cloth increased final yield and radiation use efficiency (46-50%).

Zheng and Li (1998) reported that saplings of 8 tomato cultivars in a greenhouse were shaded to 20% of natural light for 14 days. Shading decreased dry weight by 30.98 to 74.33% with the smallest effect in cv. 1239-F 2121-0. This cultivar showed no effect of shading on specific leaf weight was decreased by up to 40.03% and the leaf area by up to 3 2.21%. Shading increased plant height decreased plant dry weight at flowering.

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 or alley cropping. In an agroforestry system 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 (1999) reported that shade has pronounced effect on morphological characters of many crops. It influences plant height, stem diameter, internodes length, number of primary branches per plant, leaf number per plant, leaf size, thickness and leaf area etc. plant height increases gradually with the decrease of light levels in okra.

Different in number of primary branches per plant due to shading is important because it contributes maximum towards the yield of grain legumes. The lower number of branches under shaded condition might be due to higher auxin production in plant growth under shaded condition. This ultimately suppressed the growth of lateral branches (Miah *et al*., 1999).

Souza *et al.,* (1999) studied the effect of 3 levels of shading (0, 30, and 50%) on the development and tuberous root yield of radish *(Raphanus sativus)* under field conditions and reported that 50% level of shading increased the plant height, life cycle, foliar area and reduce leaf chlorophyll content and the tuberous root yield where the plant were evaluated at 7, 14, 21 and 28 days after emergence. The 30% level of shading did not reduce the size or weight of the root.

Bisht *et al*., (2000) showed that yield of turmeric and different fodder trees affected ginger significantly. Both turmeric (12.04 t/ha) and ginger (7.98 t/ha) gave the highest yield with *Quercus leucotrichophora*. However, the highest green forage, yield from trees was harvested from Bauhinia variegate (7.7 kg/tree).

Onwueme and Johnston (2000) studied the effect of shading on stomatal density, leaf size, leaf dry matter and leaf lamina thickness in the major tropical root and tuber crops; Tannic (*Xanthosoma sagittifolium*), Sweet potato (*Ipomoea batatas*), Yam (*Dioscorea esculenta*) and Taro (*Colocasia esculenta*). They stated that shading decreased stomatal density in the lower epidermis of tannic, sweet potato,yam and cassava. Taro under shade had an increased stomatal density in both the upper and lower epidermis shadinggenerally resulted in the production of larger size of leaves but thinner leaves in taro, sweet potato and yam.

Adams *et al.*, (2001) reported that the effect of different fruit removal and lighting/shading treatments on the pattern of amaranth (*Amaranthus lividus*), yields. While the removal of flowering trusses resulted in a yield loss about eight weeks later, Acre was little loss in cumulative yield as assimilates were distributed to neighboring trusses. Increased photosynthetic photon flux density (PPFD) for one week resulted in a period of increased yield from 4-6 weeks after the start of the treatments followed by suppressed yields due to smaller fruits on subsequent trees. Fruit size remained fairly consistent (except when fruit removal treatments were applied), whereas the number of fruits picked per week exhibited much greater variability.

Reddy *et al.,* (2002) studied that under the tree shade plant height and root length, girth, dry weight and total chlorophyll content were higher compared with those kept in the open. Root length was reduced with 60 g leaf litter/container alone or in combination with 90 g per root pieces/container. Treatment with 30 and 60g leaf litter per container reduced the shoot yield.

Liu *et al*., (2002) reported that the effects of three levels of irradiance (205.60 and 100% of full sun light at early flowering, peak flowering and late flowering stages on the photosynthetic activity and yield of tomato that three levels of irradiance were imposed for 8 days swing artificial shade net placed 2m above the plots shading increased the stomatal conductance and intercellular carbon dioxide concentrations and reduced midday photosynthetic rates at the early and peak flowering stages. However, plants at the flowering stage irradiated with 60% of the total sunlight showed increased net photosynthetic rates, total dry matter production and yield.

Senevirathna *et al.*, (2003) compared the growth, photosyntehtic performance and shade adaptation of rubber (*Hevea brasiliensis* genotypes PRRIC 100) plant growing in natural shade (33, 55 and 77% reduction in incoming radiation) to control plants growing in full sunlight. Stem diameter and plant height was greatest in plants grown in full sunlight and both parameters decreased with increasing shade. Total plant drymass was highest in control plants and lowest in plants in 77% shade. Expansion of the fourth leaf whorl, monitored at 5-6 MAP, was slowest in plants in 77% shade and fasted in shade less plants, which had more leaves and higher leaf areas and inter whorl shoot lengths. Increasing shade, specific leaf area increased whereas leaf weight ratio and relative growth rate decreased.

Rahman *et al*., (2004) reported that except plant height all others morphological characters viz. no. of branches plant^{-1}, no. of fruit plant^{-1}, fruit length, fruit diameter and fruit weight of three vegetables (Tomato, Brinjal, Chilli) were highest in open field condition. Among the different agroforestry system, highest yield was obtained in Horitoki - Lemon - Vegetable based agroforestry system.

Arun *et al.,* (2005) studied that tree growth was affected by both density and intercrop in the initial years of growth. Photosynthetic photon flux density (PPFD) available to the intercrops reduced with increasing densities. Transpiration rate and stomatal conductance in intercrops decreased due to the presence of trees. No significant changes in leaf temperature were observed till the fifth year of the growing season. Yield was significantly higher in pure crop in comparison with all the densities in mustard. Soybean yield under 200 trees ha^{-1}.

Chipungahelo *et al.,* (2007) reported that leaf morphological characteristics showed light intensity strongly influenced growth and development of sweet potato. Specific leaf area values in full light were smaller than those in under heavy shade. The light intensity increased the cowpea seed yield significantly and the interaction between seasons (year) × light regimes was significant. In low intensity, pineapple flowered earlier and yielded more than in high intensity. These results have provided useful information in planning intercropping models in coconut based–farming systems.

Islam *et al*., (2008) conducted an experiment to evaluate the performance of winter vegetables under Guava-Coconut based multistrata system. The result revealed that significantly vigorous plant growth as well as tallest plants were found under reduced light level whereas maximum yield $plot^{-1}$ and yield ha^{-1} were recorded under full sunlight condition.

Islam *et al.,* (2009) reported that morphological characteristics of winter vegetables, leaf length, leaf diameter, stem girth, fresh and dry weight decreased consistently with the decrease of distance from the tree. The growth characteristics of *Hopea oaiorata* was significantly influenced by all the three winter vegetables (red amaranth, stem amaranth and coriander).

Ding and Su (2010) reported that tree shading reduced the crop yield by 27 and 22% in western and eastern regions, respectively, and also, mean crop yield for western side was 23% lower than eastern side. The direct reason of yield variation was transpiration rate (E) variation at booting stage, that is, maize which had higher daily mean E would obtained higher yield. Moreover, changes of incident photosynthetically active radiation (PAR), air temperature (Ta) and CO2 concentration (Ca) were the basic reasons of yield variation among different regions. Because higher PAR, higher Ta and lower Ca, which caused by the tree shading, would all led to higher E and finally higher crop yield.

Monim *et al.*, (2010) reported that monoculture produce the highest yield of individual crops, all the intercropped and treatments involves red amaranth, spinach, coriander were found agronomically feasible and economically profitable.

Arya *et al.*, (2011) suggested that in growth and yield performances of trees as well as annual crops grown in combination under tree-crop farming. Plant growth and yield of all component crops were higher when grown under conjugation as compared to their sole cropping.

Schwarz *et al.*, (2014) found that the growth of the single organs demands a certain amount of carbohydrates created from photosynthesis and thus, requires a sufficient daily integral of PPFD (Photosynthetic Photon Flux Density). If this is not available, physiological disorders may occur. Plants may become very thin, leaf thickness can dramatically decrease, root growth can be reduced resulting in possible water and nutrient uptake deficiencies that can make plants more sensitive to diseases. In particular, when cultivation aims on fruit or seed production, a higher rate of carbohydrate production is required as compared to plants in their vegetative phase. Carbohydrate deficits result in restricted or suppressed fruit set. Therefore, when daily PAR is limited in the available experimental facility, the low carbohydrate production rate must be brought in line with a low development rate. This is possible in certain constraints by growing the plants at low temperatures.

2.4 Effect of Shade on Plant Growth and Development

Alley cropping Agroforestry system has been emerged as a sound technology where tree leaves are periodically pruned to prevent shading the companion crops (Kang *et al.,* 1984).

The partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73% because of reduction in number of panicles per plant (51.50%), number of grain per panicle (16.70%) and increase in number of unfilled spikelet's (41.10%) in 25 rice cultivars (Jadhav, 1987).

Rao and Mittra (1988) observed that shading by taller species usually reduces the photosynthetically active radiation which regulates photosynthesis, dry matter production and yield of crop.

The 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 (Singh *et al.,* 1989).

Jayachandran *et al.,* (1998) conducted studies in Kerala, India and indicated that the coconut (*Cocos nucifera*)- ginger (*Zingiber officinale*) system under rainfed condition gives good returns because ginger performs well under shade, where few other crops do. The yield of ginger under 0, 25, 50 and 75% artificial shade was tested.

Laosuwan *et al.,* (1992) and Miah *et al.,* (1999) found the higher yield of mungbean and onion, respectively, grown under the unshaded condition.

Effect of reduced light on four summer vegetables, such as, red amaranth. kangkong, okra and Indian spinach was reported by Wadud (1999). The light levels were 100, 75, 50 and 25 % PAR. Red amaranth and Indian spinach had been found to grow well in full sunlight while kangkong and okra showed better peribrmance under 75% PAR.

2.5 Effect of Light on Plant Growth and Development

The importance of light in the growth of plants is a well-established phenomenon. Different physiological processes of plants i.e; photomorphogenesis, evaporation, transpiration etc. are influenced by solar radiation. Light performs a major function in plant growth and development. It is essential in the production of energy that sustains life through the process of photosynthesis, the process by which plants manufacture food in the form of *sugar* (carbohydrate). In addition, it influences or controls other plant growth processes such as the synthesis of the different photoreceptors (e.g. chlorophyll, other pigments), photomorphogenesis (organ formation and development), phototropism (plant response to unilateral light), photoperiodism, translocation, stomatal movement, abscission, mineral absorption, and transpiration. (Devlin 1975; Edmond *et al*., 1978). Light is the visible portion of the solar radiation or electromagnetic spectrum**.** It is a form of kinetic energy that comes from the sun in tiny particles called quanta *or* photons, travelling in waves. Three properties of this climatic factor that affect plant growth and development are light quality, light intensity, and daylength or photoperiod. Light quality refers to the specific wavelengths of light; light intensity is the degree of brightness that a plant receives; and daylength is the duration of the day with respect to the night period. Solar radiation induced plant growth and production also depends on interception of radiation on leaf and canopy level, leaf area index etc.

Solar radiation is very important resource in multistoried production system because it is the energy source for photosynthesis and transpiration, hence growth and development of plants. But excessive density as well as excessive exposure or drastic reduction of solar energy may depress economics yield. In any agroforestry system, trees grown in close proximity to crop, often much more scope for useful management of light interception and distribution that do monoculture. Light is an essential factor on plant growth and development. The major light factors affecting plant growth are light quality, light intensity, photoperiod and day/night cycle (Goto, 2003).

Full sunlight required for optimal growth and development of many plants, particularly those grown in summer. Under light intensities of about 20 to 50% of full sunshine, maximum vegetative growth is attained. The leaves reach their greatest area, the canopy its widest diameter and the stem is maximum height (Weaver and Clements, 1973). Partial shade increases succulence and delicacy of structure. Many vegetables and some spices do best under such a condition. Diffuse light promotes the development of vegetables structures while intense light favors the development of flowers, fruits and seeds. In shorts, it may be stated that different plants and different parts of particular plant response differently at different light intensities.

2.6 Effect of Colored Shade Nets on Plant Growth and Development

Efforts to manipulate plant morphology and physiology using photoselective filters have been ongoing for decades, especially in greenhouse environments (Cerny *et al.*, 2003; Rajapakse *et al.*, 1999). More recently, colored shade netting (shade cloth) designed specifically for manipulating plant development and growth has become available. These nets can be used outdoors as well as in greenhouses. They can provide physical protection (birds, hail, insects, excessive radiation), affect environmental modification (humidity, shade, temperature) (Pe´rez *et al*., 2006), and increase the relative proportion of diffuse (scattered) light as well as absorb various spectral bands, thereby affecting light quality.

According to Valli, *et al*., (1965) incoming radiation in the open is composed of solar and atmospheric radiation. Under the shade net there is also the net reflected and net radiated energy, less the amount of incident energy which is reflected and radiated by the top of the shade back into the atmosphere. Incoming radiation at the soil surface under the shade is affected by the shade net. The net reflects a portion of the total energy incident upon it and absorbs some of the energy which is then reradiated out as long wave energy.

These effects can influence crops as well as the organisms associated with them. Colored shade netting is a relatively new tool that can be used for a wide variety of purposes by horticulturists. However, the effects are varied and plant responses may differ even among cultivars of the same plant. Robert H. Stamps (2009) suggested that colored netting has numerous effects besides photoselective ones, and even photoselectivity can change over time, it is important that researchers provide careful and complete descriptions of experimental conditions. Radiation quality and quantity values and microclimate parameters should be measured and reported to aid in the determination of which factors might be causing any reported results.

2.7 Importance of Summer Vegetable Crops

Vegetables are usually recognized as cheap, easily available sources of carbohydrates, proteins, minerals and vitamins. Importance of six studied summer vegetables namely Indian Spinach, Data, Kangkong, Okra, Eggplant, Chilli are as follows:

2.7.1 Importance of Indian spinach

Indian spinach (*Basella alba* L.) commonly known as *pui* and belongs to the family Basellaceae. There are mainly two distinct types, *Basella alba* and *Basella rubra,* one with green petioles and stems and the other with reddish leaves, petioles and stems. Both the green and red leaved cultivers are consumed as vegetables but green-leaved cultivers are commercially cultivated.

The nutritive value of Indian spinach is very high with a good content of minerals and a moderate storage of vitamins to the human diet plus substantial amount of fibre and that of water (Ghosh and Guha, 1933), the plant is reported to contain the following salts and vitamins. Moisture -93%, Protein -1.2%, Iron -1.4%, Calcium – 0.15%, Vitamin A – 3250 IU/100g. There was no loss of nitrate even after 48hrs of cold storage. Moreover, it is anadyne, sedative, diuretic and expectorant (Kallo, 1986).

2.7.2 Importance of Danta (Stem amaranth)

Stem amaranth (*Amaranthus viridus*) belongs to the family Amaranthaceae is commonly known as ‘Danta’ and used as leafy as well as stem in Bangladesh.

Stem amaranth is considered to be the cheapest vegetable in the market that is why it is called poor man’s vegetable (Shanmugavelu, 1989). Stem Amaranth is fairly rich in vitamin A and ascorbic acid. It has an appreciable amount of iron, calcium, phosphorous, riboflavin, thiamine, niacin and iron (Thompson and Kelly, 1988). Per 100 g of edible portion it contains 43 caloric which is higher than those of other vegetables except potato and taro (Chowdhury, 1967). During Kharif season vegetable production in our country is very low. The maximum production of different vegetables is concentrated during the months of November and April that is especially in winter season. Thus, there is a serious scarcity of vegetables during the months of May to September in the market. As a result the nation runs short of vegetables, its production should be increased to meet up the shortfall and feed the ever increasing population of the country.

2.7.3 Importance of Kangkong

Kalmi or Gimakalmi (*Ipomoea reptans*poir) is a leafy vegetable, belongs to the family Convolvulaceae. The crop is also known as kangkong, swamp cabbage, water convolvulus, water spinach etc. (Tindal, 1983). Introduction of Gimakalmi is a positive achievement since it can be grown in summer and rainy season (Shinohara, 1980).

Like other leafy vegetable, it is nutritionally rich in vitamins, minerals, calories etc. It is an excellent source of Vitamin A. Leafy vegetable of 100 g of its edible portion contains 87.6 g water, 1.1 g minerals, 0.1 g fat, 9.4 g carbohydrates, 107 mg calcium, 3.9 mg iron, 10740 microgram carotene, 0.14

mg vitamin B_1, 0.40 mg vitamin B_2, 42 mg vitamin C, 1.8 g protein and 46 kilocalories (Anon., 1983).

2.7.4 Importance of Okra

Okra (*Abelmoschus esculentus* (L.) Moench) originated in Asia and Africa (Thomson and Kelly, 1988) is an important summer vegetable in Bangladesh (Rashid, 1999), belongs to the Malvaceae family.

The composition of okra pods per 100 g edible portion (81% of the product as purchased, ends trimmed) is: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g,Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, β-carotene 185.00 μg, riboflavin 0.08 mg, thiamin 0.04 mg, niacin 0.60 mg, ascorbic acid 47.00 mg. Carbohydrates are mainly present in the form of mucilage . Fresh pods are low in calories (20 per 100 g), practically no fat, high in fiber, and have several valuable nutrients, including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20% of folate (46 to 88 mg) and about 5% of vitamin A (14 to 20 RAE).

2.7.5 Importance of Eggplant

Brinjal or Eggplant (*Solanum melongena* L.) is also known as Aubergine or Guinea squash an economically important vegetable crop widely cultivated in the tropics, subtropics and warm temperate regions (Sihachakr et al. 1994). It belongs to the Solanaceae family. It is a versatile crop adapted to different agro-climatic regions and can be grown throughout the year. It is a perennial but grown commercially as an annual crop. The fruits are known for being low in calories and having a mineral composition beneficial for human health. It is also a rich source of Potassium, Magnesium, Calcium and Iron (Zenia and Halim, 2008). Per 100 g of edible portion it contains the following proportion of food values- Water- 93 g, Vit-A- 70 IU, Protein – 1.2 g, Thiamine- 0.05 mg, Fat – 0.1 g, Riboflavin – 0.08 mg, Carbohydrate- 4.0 g, Niacin – 0.09 mg, Fibre – 1.2 g, Calories- 20, Calcium- 16 mg, Fe – 0.9 mg (Bose and Some, 1986). Brinjal is known to have ayurvedic medicinal properties and is good for diabetic patients. It has also been recommended as an excellent remedy for those suffering from liver complaints (Shukla and Naik 1993).

2.7.6 Importance of Chilli

Chilli (*Capsicum annum* L) belongs to the genus Capsicum under the family Solanaceae. Chemical analysis has shown that the red chilli pod contains 15.9% protein, 31.6% carbohydrate, 50 mg /100g Vitamin C, small quantities of minerals, Vitamin A, Vitamin B (Pruthi, 1998). The green chilli pod contains 2.9% protein, 6.1% carbohydrate, 111.0 mg/100 g Vitamin C and small quantities of Vitamin A, B and E. The pungent nature of chilli is due to crystalline volatile alkaloid substance called capsicin ($C_9H_{14}O_2$).

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted to find out higher yielding and partial shade tolerant summer vegetables under reduced light levels i.e., full sunlight and reduced light intensity based agroforestry system during the period from March to June, 2014. In this chapter the materials used, the methodologies followed and the related works done during experimental period are presented. A brief description on the experimental site and season, soil, climate and weather, plant materials, land preparation, fertilizer application, experimental design and treatment combination, seed sowing, intercultural operation, harvest, data collection, statistical analysis etc. are included here. The working procedures have been given below:

3.1 Experimental site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989).

3.2 Soil

The soil of the experimental field belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was sandy loam with pH and Cation Exchange Capacity (CEC) 5.6 and 2.64 meq 100 g soil^{-1}, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I (Khatun, 2014).

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly maximum and minimum temperature, relative humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and have been presented in Appendix II.

3.4 Shade and plant materials

In this study artificial shading was created by dark coffee colored mosquito net. Four pieces of bamboo stakes were pegged at four corners of the shade treatment plots. The dark coffee colored mosquito net was then spread over the stakes to cover the plants from all sides as well as. Care was taken to keep the mosquito net shade in proper condition with progressive rate of growth and yield of the plants.

As summer vegetable V_1= Indian Spinach, V_2= Danta (Stem amaranth), V_3=Kangkong, V_4= Okra, V_5= Eggplant, V_6= Chilli were used and the seeds and seedlings of these vegetables were collected from Siddique Bazar, Dhaka. These six summer vegetables were used as planting materials in this study.

3.5 Treatments of the experiment

1. T_{sun} - Planting summer vegetables under full sunlight (open field condition)
2. T_{shade} – Planting summer vegetables under reduced light intensity (severe shaded condition).

In treatment T_{sun} sunlight was allowed to fall over the leafy and fruit vegetables without any barrier which was considered as full sunlight level.

In treatment T_{shade}, plants were grown under dark coffee colored mosquito net which permitted reduced light intensity or PAR (Photosynthetically Active Radiation) to reach to the vegetables under artificial shade.

3.6 Experimental design and Layout

Six summer vegetables viz. Indian Spinach, Danta, Kangkong, Okra, Eggplant, Chilli were sown under full sunlight (100% PAR) and shade following the Randomized Complete Block Design (RCBD) with single factor experiment. Two treatments were used in this experiment. Three replications were used for each treatment for each crop. So, there were in total 12 (6×2) treatment combinations such as V_1T_{shade}, V_2T_{shade}, V_3T_{shade}, V_4T_{shade}, V_5T_{shade}, V_6T_{shade}, V_1T_{sun}, V_2T_{sun}, V_3T_{sun}, V_4T_{sun}, V_5T_{sun}, V_6T_{sun} and total 36 (12×3) plots were set up. Individual plot size for vegetables were 2.5m×2m. Adjacent plots and neighboring blocks were separated by 0.5m and 1m respectively. (Appendix III)

3.7 Land preparation

The land was opened in 13th March of 2014 and then prepared thoroughly by tractor and spading also. Harrowing was done for several times to obtain a good tilth condition. The weeds and stubbles were removed from the field and the bigger clods were broken into smaller pieces. Then the land was kept fallow for few days. All crop residues and weeds were removed from the field and finally the land was properly leveled. Land layout design and seedbed preparation was done on 15th March, 2014.

3.8 Crop establishment and management

3.8.1 Seed sowing

Among six summer vegetables Indian Spinach, Danta, Kangkong, Okra were directly sown in the experimental plot on 7th April, 2014. Seeds of Indian Spinach, Danta, Kangkong, Okra were sown in line sowing method. 15 days old seedlings of Eggplant and Chilli plant were transplanted in the assigned plots after the emergence of Indian Spinach, Danta, Kangkong, Okra. The leafy vegetable (Indian Spinach, Danta, Kangkong) seeds were sown maintaining the spacing of 50 cm from one line to another while fruit vegetable seedlings were sown maintaining 75 cm spacing. One day after sowing of seeds, light irrigation was given to facilitate the germination process.

3.8.2 Fertilizer application

Recommended dose of well decomposed cowdung were applied for all the crop species. Chemical fertilizer was applied as per the BARI recommendation fertilizers of this crop. Full amount of P, K and well decomposed cowdung was incorporated during the final land preparation. Nitrogen fertilizers were applied in three equal installments (Rashid, 1999).

For Indian Spinach

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	20 ton	100	- -	- -	- -
Nitrogen as Urea	200 kg	- -	33.33	33.33	33.33
P_2O_5 (as TSP)	100 kg	100	- -	- -	- -
K_2O (as MP)	200 kg	100	- -	- -	- -

For Data (Stem Amaranth)

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	20 ton	100	- -	- -	- -
Nitrogen as Urea	200 kg	- -	33.33	33.33	33.33
P_2O_5 (as TSP)	100 kg	100	- -	- -	- -
K_2O (as MP)	200 kg	100	- -	- -	- -

For Kangkong

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	10 ton	100	- -	- -	- -
Nitrogen as Urea	200 kg	- -	33.33	33.33	33.33
P_2O_5 (as TSP)	100 kg	100	- -	- -	- -
K_2O (as MP)	80 kg	100	- -	- -	- -

For Okra

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	15 ton	100	- -	- -	- -
Nitrogen as Urea	150 kg	50	25	25	- -
P_2O_5 (as TSP)	100 kg	100	- -	- -	- -
K_2O (as MP)	150 kg	100	- -	- -	- -

For Eggplant

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cowdung	10 ton	100	- -	- -	- -
Nitrogen as Urea	375	- -	33.33	33.33	33.33
P_2O_5 (as TSP)	150	100	- -		
K_20 (as MP)	250	- -	33.33	33.33	33.33
Gypsum	100	100			

For Chilli

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	25 DAS	50 DAS	75 DAS
Cowdung	10 ton	100	- -	- -	- -
Nitrogen/ Urea	200 kg	50	16.67	16.67	16.67
P_2O_5 (as TSP)	100 kg	100	- -	- -	- -
K_20 (as MP)	80 kg	100	- -	- -	- -

3.8.3 Thinning and Gap filling

Thinning was done in case of Stem Amaranth after the emergence to maintain the proper plant stand. Gap filling was done in case of Indian Spinach, 10 days after the emergence to maintain the uniform plant growth.

3.8.4 Plant protection

At early stage of growth few leaf miners (*Agrotis ipsilon*) infested the young plants and at later stage of growth borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mm with 1 litre water for two minutes at 15 days interval after seedling germination to control the insects.

3.8.5 Weeding and irrigation

To keep the plots free from weeds, weeding was done five times for experimental plots and control plots. The plots were irrigated seven times by using hose pipe and water cane to supply sufficient soil moisture for the vegetables.

3.9 Harvesting

Kangkong and Indian spinach were harvested for 3 times; first harvesting was done after 60 days of seed sowing. Stem Amaranth was harvested for 1 time for final harvesting. Okra was harvested for 3 times for a period of 15 days long at

5 days interval. Fruits of Chilli and Eggplant was also harvested for one time at the time of harvesting.

3.10 Sampling procedure and data collection

Plant samples were collected randomly from all rows of the respective plots. Five representative sample plants were selected from each row per plot for data collection. Sample plants were collected based on suitable size for consume.

In case of Indian Spinach, Danta (Stem Amaranth) and Kangkong

- Plant height, number of leaves per plant, number of branches per plant, plant diameter, leaf chlorophyll content, height from base to crown, width of crown was recorded at 15, 30, 45 and 60 DAS (Days After Sowing).
- In case of Indian Spinach and Kangkong yield/plot and yield/hectare was recorded at 30, 45 and 60 DAS.
- In case of Stem Amaranth yield/plot and yield/hectare was recorded at 60 DAS.

In case of Okra, Eggplant and Chilli

- Plant height, number of leaves per plant, number of branches per plant, plant diameter, leaf chlorophyll content, height from base to crown, width of crown was recoeded at 15, 30 and 45 DAT (Days After Transplanting).
- In case of Okra flower cluster per plant was recorded at 30 DAT and fruits per plant, single fruit weight, single fruit length, single fruit girth, yield/plot and yield/hectare was recordedat 45, 60 and 75 DAT.
- In case of Eggplant and Chilli flower cluster per plant was recorded at 35 DAT and fruits per plant, single fruit weight, single fruit length, single fruit girth, yield/plot and yield/hectare was recorded at 75 DAT.

3.11 Light measurement

Light was measured by Lux meter on each vegetable crop rows. It was done to determine the extent of shading by the artificially created shade and expressed as lux. Light intensities were measured above the canopy of vegetable crops at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm using Lux meter at three times per month and collected data were averaged and expressed as lux.

3.12 Soil moisture measurement

Soil moisture was measured by Soil Moisture Meter on each vegetable crop rows. It was expressed as percentage (%). Soil moisture was measured 10 cm depth of soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.13 Soil temperature measurement

Soil temperature was measured by Soil Temperature Meter on each vegetable crop rows. It was expressed as degree centigrade (˚C). Soil temperature was measured 10 cm deep soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.14 Leaf Chlorophyll Measurement

Leaf chlorophyll content was measured by SPAD meter whose model number was SPAD-502 Plus. Foliar chlorophyll content was measured by placing the SPAD meter at three positions of the particular leaf from which data were taken at 15 days interval. Then collected data were averaged and expressed as SPAD unit.

3.15 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of summer vegetables under reduced light conditions based agroforestry system. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 1% and 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Experimental results obtained from the present study on performance of summer vegetables under reduced light condition in agroforestry system were discussed in the results and discussion chapter. The analysis of variance (ANOVA) of the data on different recorded parameters have been presented in Appendix IV to IX. The results have been presented with the help of tables and graphs and possible interpretations have been given under the following headings.

4.1 Climatic Parameters

4.1.1 Light Availability on the Crop Rows

Plants require solar radiation for photosynthesis, and their growth rate is proportional to the amount received, assuming that other environmental parameters are not limiting. Visible light is a composite of wavelengths between 400 and 700 nanometers (nm), and this specific waveband is defined as PAR (photosynthetically active radiation). PAR consists of wavelengths that are utilized by the plant in the processes of photosynthesis to convert light energy into biomass (i.e; carbon molecules (sugars) that are then used to construct more complex compounds, and ultimately plant cells and organs (root, leaf, stem, flower, fruit).

Light availability was measured to determine the extent of limiting radiation by shade net on the understorey vegetable rows. Light for different crops in sun and shade conditions which was measured as presented below-

Table 1: Light availability in the different crop rows from March to June 2014

Light condition (kilo lux)	Indian Spinach	Stem Amaranth	Kangkong	Okra	Eggplant	Chilli
Shade	42.02	48.27	46.28	37.51	48.78	43.67
Sun	67.43	68.90	64.70	62.43	65.39	75.58
Reduction of light	22%	29.9%	28.41%	39.9%	25.42%	42.23%

From the table it is seen that during the study period maximum light intensity reduction was recorded in Chilli (42.2%) and minimum light intensity was reduced in case of Indian Spinach (22%) under shade. This may happen as Chilli plants don't thrive well in shade and absorbs little light in shade. On the other hand Indian Spinach absorbs maximum light and grow well in shade condition.

4.1.2 Soil Temperature

Mean monthly soil temperature for March was 32.3^{0}c in the shade compared to 33.5^{0}c in the open. The highest temperature was recorded in April- 35.7°C in sun and 34.2°C in shade. In the months of May and June soil temperature was reduced from 34.7°C to 33.7°C in open condition and from 33.5°C to 32.1°C in shaded condition. This has been presented as the graphical presentation as below -

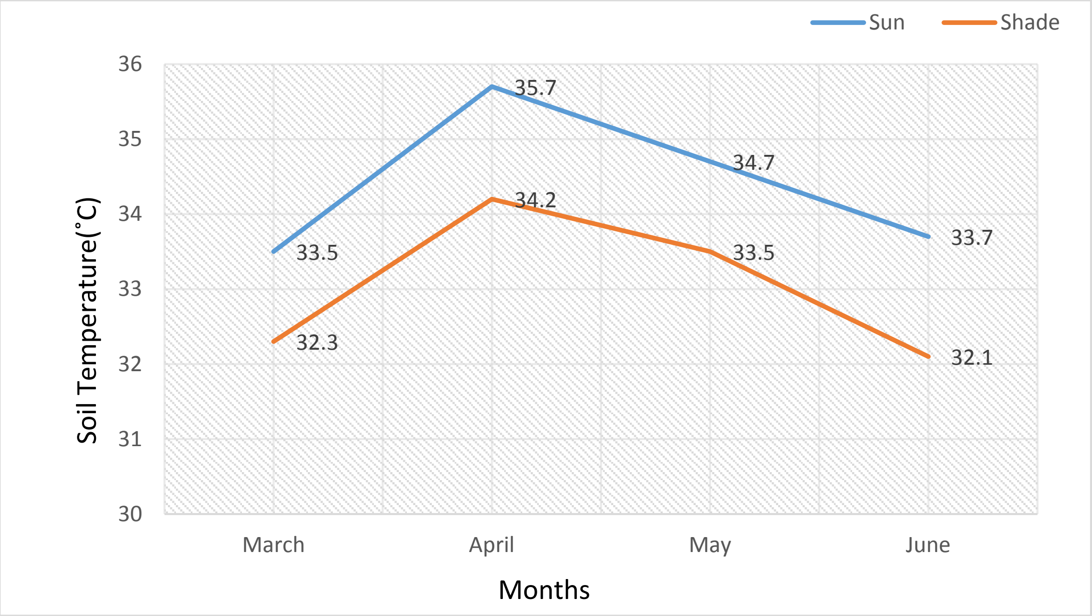

Figure 1: Sun and Shade effects on soil temperature from the months of March to June 2014

4.1.3 Soil Moisture

Mean monthly soil moisture for March was 15.3% in the shade compared to 18.5% in the open. The soil moisture was reduced in sun to 13.7% and increased to 16.8% in the shade. The highest soil moisture was recorded in June both in open and shade as 39.3% and 28.5% followed by May where soil moisture was 27.8% and 22.3% in sun and shade respectively. This is presented as the graphical presentation as below -

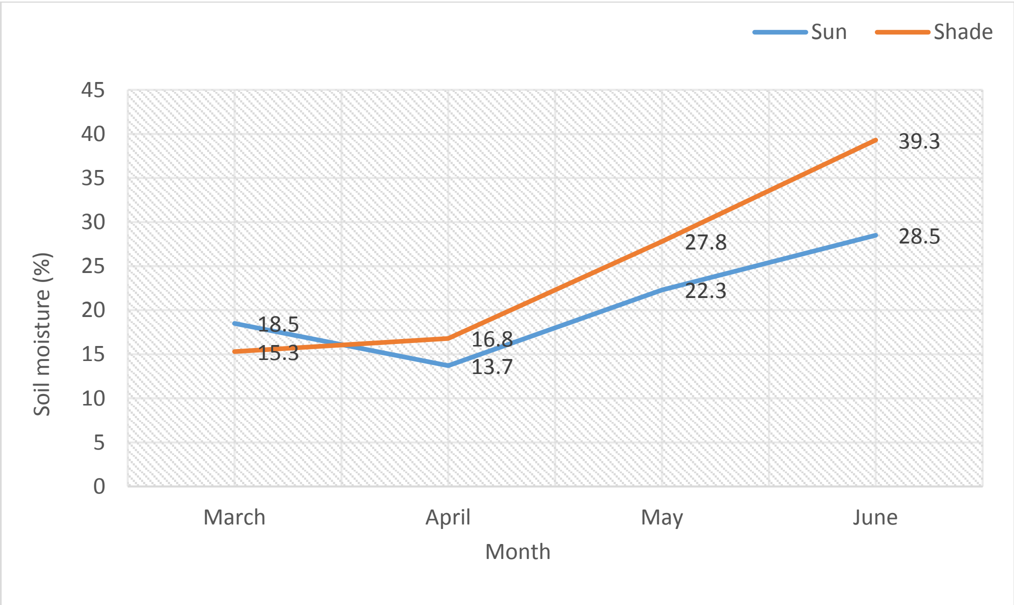

Figure 2: Sun and Shade effects on soil moisture from the months of March to June 2014

4.1.4 Soil moisture and temperature effects on six summer vegetables in May 2014

Sun and shade effects on soil moisture and ultimate effect on Indian spinach, Data, Kangkong, Eggplant, Okra and Chilli were recorded and significant variations were found. In case of Eggplant, Indian Spinach and Data, highest soil moisture in sun (24.2%, 24.1% and 21.2% respectively) was observed while the highest soil moisture in shaded condition was recorded in Eggplant, Chilli and Indian Spinach (29.6%, 29.4% and 28.5% as respectively). The lowest soil moisture (14.5% in sun, 19.3% in shade followed by 16.4% in sun, 21.4% in shade) was found in Kangkong and Okra field respectively (Figure 3).

Sun and shade effects of soil temperature on Indian spinach, Data, Kangkong, Eggplant, Okra and Chilli were recorded and found significant differences. The highest soil moisture was recorded in Chilli field (37.6% in sun and 35.3% in shade) while in other fields the differences were significantly similar (Figure 4).

Soil moisture and temperature effects on six summer vegetables in May 2014: was recorded which has been shown as the graphical presentation as below-

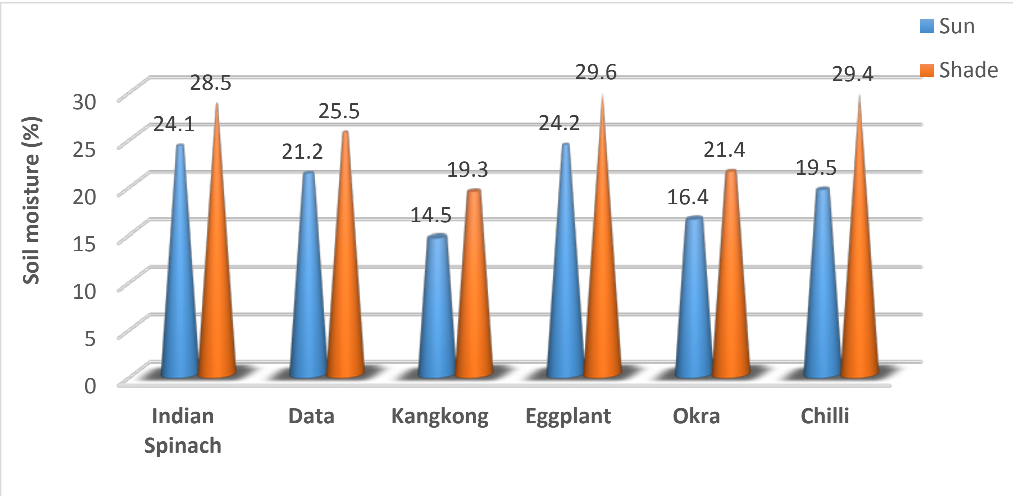

Figure 3: Soil moisture effects on six summer vegetables in May 2014

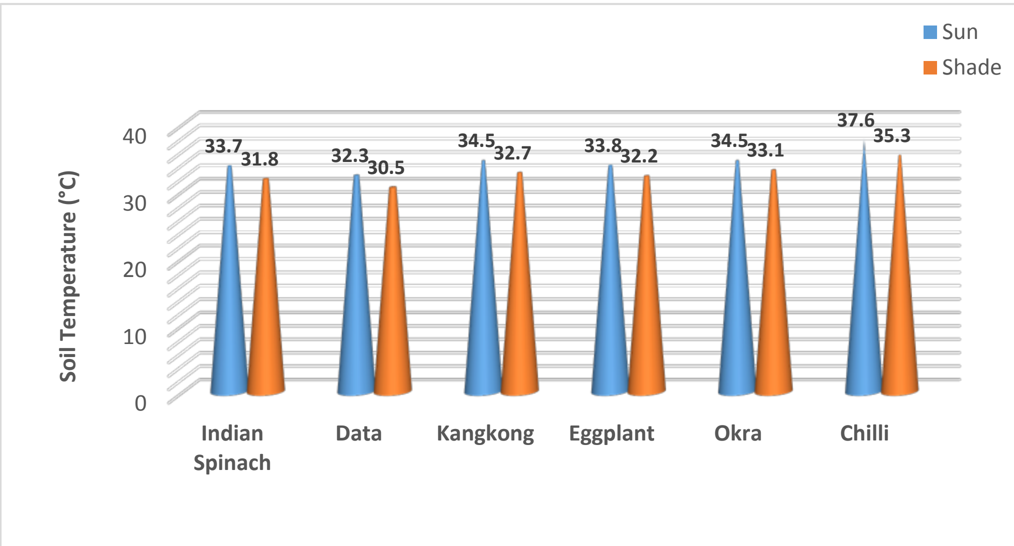

Figure 4: Soil temperature effects on six summer vegetables in May 2014

4.2 Morphological characteristics of summer vegetables under reduced light condition

4.2.1 INDIAN SPINACH

Plant Height

The highest plant height of Indian Spinach (56.28 cm) was found in reduced light condition based agroforestry system (T_{shade}). Indian Spinach cultivated under shade grew more vigorously than those grew in the open field. It exhibited significantly highest height irrespective of shaded condition (Appendix iv). This was probably due to higher apical dominance under shade condition (Hillman, 1984). With the increase of shade levels plant height increased significantly. The minimum height (46.00cm) was found in full sunlight condition under T_{sun} (Table 2). Similar to this crop higher plant height under reduced light levels was observed in mungbean (Islam, 1996) and in chickpea (Murshed, 1996). This may be attributed due to the stimulation of cellular expansion and cell division under shaded condition (Schoch, 1972).

Number of leaves per plant

Total number of leaves per plant of Indian spinach was also significantly influenced by reduced light level (Table 2). This parameter showed an inverse trend to that of plant height as it decreased with decreasing percent of light level. The higher number of leaves per plant was seen in sunlight (215.00 cm) (T_{sun}) compared to that of shade condition (110.80 cm) (T_{shade}). The lower number of leaves per plant at reduced light condition may be due to lower production of photosynthates under low light conditions for a longer period.

Table 2. Growth and yield contributing characters of Indian spinach under control (full sunlight) and reduced light

Treatment combination	Plant height (cm)	No. of leaves/ plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/ plot)	Yield (ton/ha)
T_{shade}	**56.28**	**110.80**	**6.35**	**15.55**	**52.37**	**16.95**	**42.58**	**2.83**	**5.67**
T_{sun}	**46.00**	**215.00**	**7.62**	**18.00**	**40.73**	**16.36**	**24.13**	**4.47**	**8.93**
CV%	2.74	2.77	2.12	3.79	2.86	2.42	3.91	10.21	9.69
$LSD_{0.05}$	4.91	15.88	0.52	2.24	4.67	1.42	4.58	1.31	2.48
$LSD_{0.01}$	11.32	36.62	1.20	5.16	10.77	3.27	10.58	3.02	5.73
Level of significance	**	**	**	*	**	NS	**	*	*

T_{sun} = Planting summer vegetables under full sunlight

T_{shade} = Planting summer vegetables under reduced light

* = 5% level of significance

** = 1 % level of significance

Number of branches per plant

The effect of reduced light level on the number of branch per plant was almost similar to the number of leaves per plant (Table 2 and Appendix IV), where the higher number of branches was recorded under full sunlight (T_{sun}) (7.62) compared to that of shaded (T_{shade}) condition (6.35). The lower number of branches under shaded condition might be due to higher Auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al.*, 1999).

Plant Diameter

Plant diameter of Indian spinach was significantly influenced by reduced light level (Table 2). Plant diameter of indian spinach grown under full sunlight (T_{sun}) was recorded as 18.00 mm but it was reduced when grown under reduced light (T_{shade}) level (15.55mm).

Leaf Chlorophyll Content

Leaf chlorophyll content of Indian Spinach was lower (40.73 SPAD unit) in full light (T_{sun}) level than that of shade condition (reduced light level under T_{shade}) 52.37 SPAD unit. This may be due to in shaded condition leaves were more green for a longer period of time than full sunlight condition. In full sunlight leaves were thrived in more light so they were yellowed.

Height from base to crown (cm)

Height to base of crown had no significant response statistically under different sunlight levels (Appendix IV). Highest height to base of crown was found in shade (16.95 cm) and lowest height to base of crown was observed in full sun (16.36 cm)

Width of crown (cm)

Reduced light level had significant influence on the width of crown of Indian Spinach. It was found that the highest width of crown was found in T_{shade} condition (42.58 cm) and lowest in open field condition (T_{sun}) (24.13 cm).

Yield per plot and per hectare

There were significant variations in respect of yield/plot and yield/hectare of Indian spinach by the reduced light level (Appendix IV). The highest yield/plot (4.47 kg) and yield/hectare (8.93t) were found when Indian spinach grown under full sunlight condition (T_{sun}). On the other hand, the lowest yield/plot (2.83 kg) and yield/hectare (5.67 t) were recorded when Indian spinach was cultivated under shade condition (T_{shade}) (Table 1 and Appendix IV).

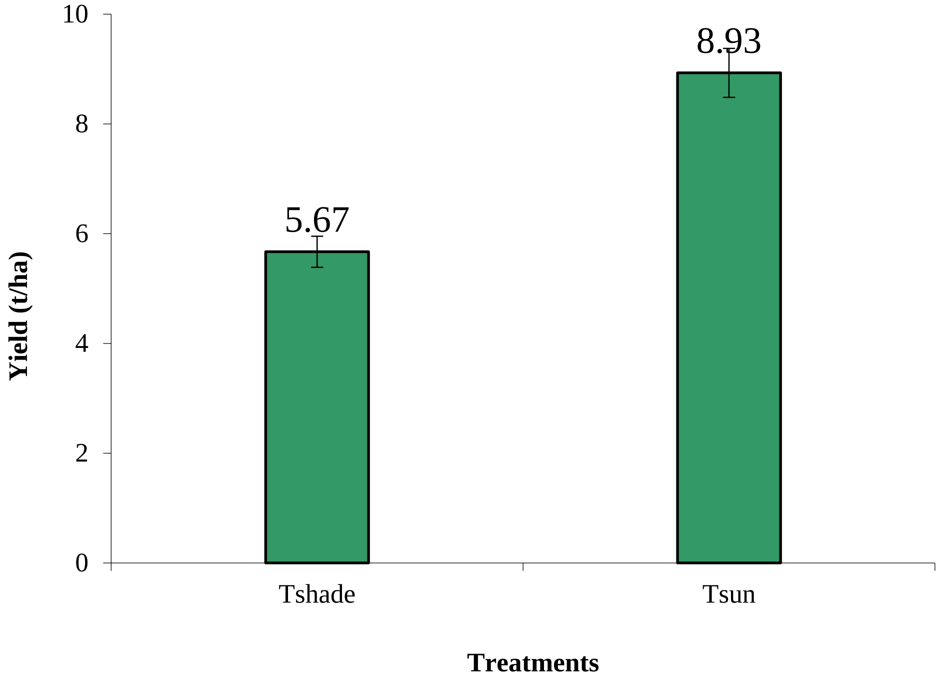

Figure 5: Yield of Indian spinach at shade and non-shade

Plate 1: Indian spinach in shade condition

4.2.2 Danta (Stem Amaranth)

Plant Height

Plant height of Danta grown under different light levels was influenced significantly (Table 3). The plant height increased with increased shade level. This was probably due to higher apical dominance under shade condition (Hillman, 1984). In 100% light or in sunlight (T_{sun}) plant height was 82.26 cm whereas in shade condition (T_{shade}) it was increased to 109.11 cm. Leonardo (1996) found increased plant height, stomata density, transpiration rate and photosynthesis rate in Peppers at low PAR condition. This may be attributed due to the stimulation of cellular expansion and cell division under shaded condition (Schoch, 1972).

Table 3. Growth and yield contributing characters of Stem Amaranth under control (full sunlight) and under reduced light

Treatment combination	Plant height (cm)	No. of leaves / plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
T_{shade}	**109.11**	**84.33**	**19.04**	**25.22**	**55.00**	**46.13**	**44.70**	**12.89**	**25.77**
T_{sun}	**82.26**	**114.00**	**23.44**	**35.23**	**45.90**	**51.39**	**48.83**	**13.84**	**27.67**
CV%	6.16	3.43	3.46	7.30	4.86	2.57	2.24	0.46	2.69
$LSD_{0.05}$	21.06	11.94	2.58	7.75	8.61	4.41	3.68	0.97	2.52
$LSD_{0.01}$	48.58	27.53	5.96	17.89	19.85	10.17	8.48	1.92	5.82
Level of significance	*	**	**	*	*	*	*	NS	NS

T_{sun} = Planting summer vegetables under full sunlight
T_{shade} = Planting summer vegetables under reduced light
* = 5% level of significance
** = 1 % level of significance

Number of leaves per plant

Number of leaves per plant of Danta or Stem amaranth was recorded and found significant differences due to the effect of reduced light (T_{shade} = Planting summer vegetables under reduced light). The higher number of leaves per plant was seen in sunlight (114.00) compared to that of shade condition (84.33). The lower number of leaves per plant at reduced light condition may be due to lower production of photosynthates under low light conditions for a longer period.

Number of branches per plant

The effect of reduced light level on the number of branch per plant was almost similar to the number of leaves per plant (Table 3 and Appendix V), where the higher number of branches was recorded under 100% light level (T_{sun}) (23.44) compared to that of shaded reduced light level (T_{shade}) condition (19.04). The lower number of branches under shaded condition might be due to higher Auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al*., 1999).

Plant diameter

Plant diameter of Stem amaranth was significantly influenced by reduced light level (Table 3 and Appendix V). Maximum plant diameter of Stem amaranth was observed under full PAR (T_{sun}) as 35.23 mm and minimum plant diameter was found when grown under reduced light (T_{shade}) level (25.22 mm).

Leaf chlorophyll content

Leaf chlorophyll content of Stem amaranth was lower (45.90 SPAD unit) in full sunlight (T_{sun}) than that of shade condition (reduced light level under T_{shade}) 55.00 SPAD unit. This may be due to in shaded condition leaves were more green for a longer period of time than full sunlight condition. In full sunlight leaves were thrived in more light so they were yellowed.

Height from base to crown (cm)

Height from base to crown was significantly influenced in case of Stem amaranth by reduced light level (Table 3 and Appendix V). Highest height from base to crown (51.39 cm) was observed under full sunlight condition under the treatment T_{sun} while the lowest height to base of crown (46.13 cm) was seen in shade condition under the treatment $T_{shade,}$

Width of crown (cm)

Reduced light level had significant influence on the width of crown of Stem amaranth. From the Table 3 it was found that the highest width of crown (48.83 cm) was found in open field (T_{sun}) condition and lowest (44.70 cm) in reduced light level- shade condition under the treatment T_{shade}.

Yield per plot and per hectare

Yield per plot of Stem amaranth was not varied significantly with the different light levels (Appendix V). The highest yield per plot (13.84 kg) was found when Stem amaranth grown under full sunlight condition (T_{sun}). On the other hand, the lowest yield per plot (12.89 kg) was recorded when Stem amaranth was cultivated under shade condition (T_{shade}) (Table 3 and Appendix V). As well as yield per hectare was not significantly respond with the shade treatment (T_{shade}). Highest yield per hectare (27.67 ton) was recorded in sun and lowest (25.77 ton) was in shade.

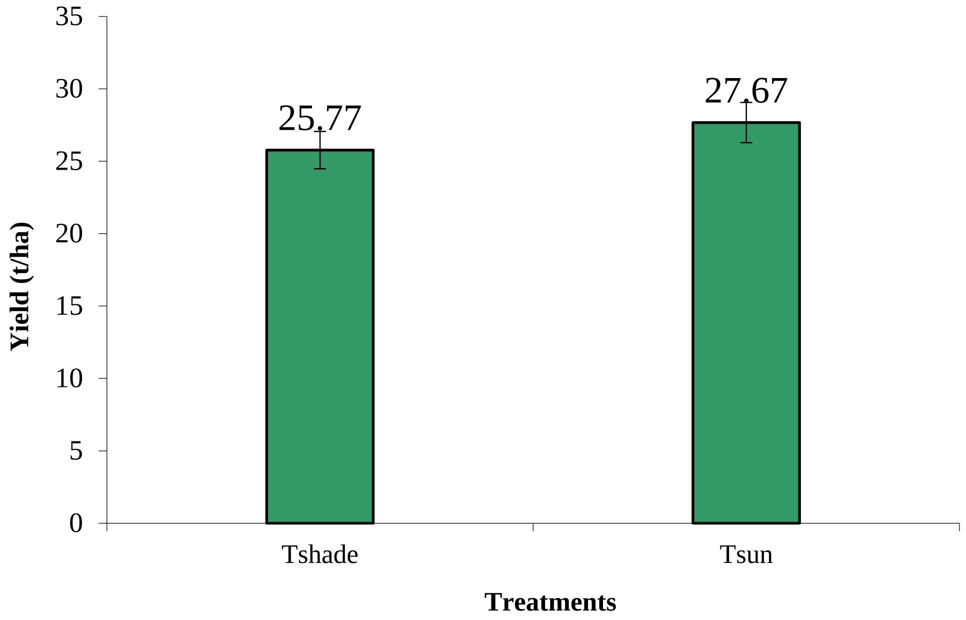

Figure 6: Yield of Stem amaranth at shade and sun

Plate 2: Danta (Stem amaranth) plants growing under shade condition

4.2.3 KANGKONG

Plant height

Kangkong was cultivated under full sunlight and shade condition and plant height was recorded. It grew vigorously in the shaded condition under the treatment T_{shade}. Plant height of Kangkong was significantly influenced by shade (Table 4 and appendix VI). It increased with increasing shade level. Under the treatment T_{sun} , plant height was 51.45 cm whereas in case of shade condition it was remarkably increased to 61.50 cm. Plant grown in low light levels was found to be more apically dominant than those grown in high light levels resulting in taller plants under shade (Hillman, 1984).

Table 4. Growth and yield contributing characters of kangkong under control (full sunlight) and under reduced light

Treatment combination	Plant height (cm)	No. of leaves / plant	No. of branch /plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height to base of crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
T_{shade}	**61.50**	**184.85**	**18.00**	**10.60**	**46.93**	**23.34**	**76.15**	**9.33**	**18.67**
T_{sun}	**51.45**	**185.00**	**21.44**	**7.76**	**43.77**	**16.38**	**57.08**	**6.47**	**12.97**
CV%	2.21	1.75	2.92	5.05	1.29	1.29	1.23	3.74	4.98
$LSD_{0.05}$	4.39	11.38	2.02	1.63	2.05	0.90	2.88	1.04	2.77
$LSD_{0.01}$	10.13	26.26	4.67	3.76	4.73	2.07	6.63	2.39	6.38
Level of significance	**	NS	**	**	*	**	**	**	**

T_{sun} = Planting summer vegetables under full sunlight
T_{shade} = Planting summer vegetables under reduced light
* = 5% level of significance
** = 1 % level of significance

Number of leaves per plant

Total number of leaves per plant of Kangkong was not significantly influenced by reduced light level (Table 4 and Appendix VI). Higher number of leaves per plant was 185 in sun and 184.85 in shade.

Number of branches per plant

The higher (21.44) number of branches was recorded under 100% light level (T_{sun}) compared to that of shaded reduced light level (T_{shade}) condition (18.00). The lower number of branches under shaded condition might be due to higher Auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al*., 1999).

Plant diameter

Plant diameter of Kangkong was significantly influenced by reduced light level (Table 4). Maximum (10.60 mm) plant diameter of Kangkong was observed under reduced light (T_{shade}) level and minimum (7.76 mm) plant diameter was found when grown under full sunlight (T_{sun}).

Leaf chlorophyll content

Leaf chlorophyll content of Kangkong was lower (43.77 SPAD unit) in sun (T_{sun}) level than that of shade condition (T_{shade}) (46.93 SPAD unit). This may be due to in shaded condition leaves were more green for a longer period of time than full sunlight condition. In full sunlight leaves were thrived in more light so they were yellowed.

Height from base to crown (cm)

Height from base to crown was significantly influenced in case of Kangkong by reduced light level (Table 4). Highest height from base to crown (23.34 cm) was observed under shade condition under the treatment $T_{shade,}$ while the lowest height from base to crown (16.38 cm) was seen in full sunlight condition under the treatment T_{sun}

Width of crown (cm)

Reduced light level had significant influence on the width of crown of Kangkong. From the Table it was found that the highest width of crown (76.15 cm) was found in reduced light level- shade condition under the treatment T_{shade} and lowest (57.08 cm) in open field (T_{sun}) condition.

Yield per plot and per hectare

It was observed that there were significant difference in respect of yields per plot and per hectare of Kangkong by the shade level (Appendix VI). The highest yield per plot (9.33 kg) and yield per hectare (18.67t) were found when kangkong grown under shade condition (T_{shade}). On the other hand, the lowest yield per plot (6.47 kg) and yield per hectare (12.97 t) were recorded when Kangkong was cultivated under full sunlight condition (T_{sun}). (Table 4 and Appendix VI).

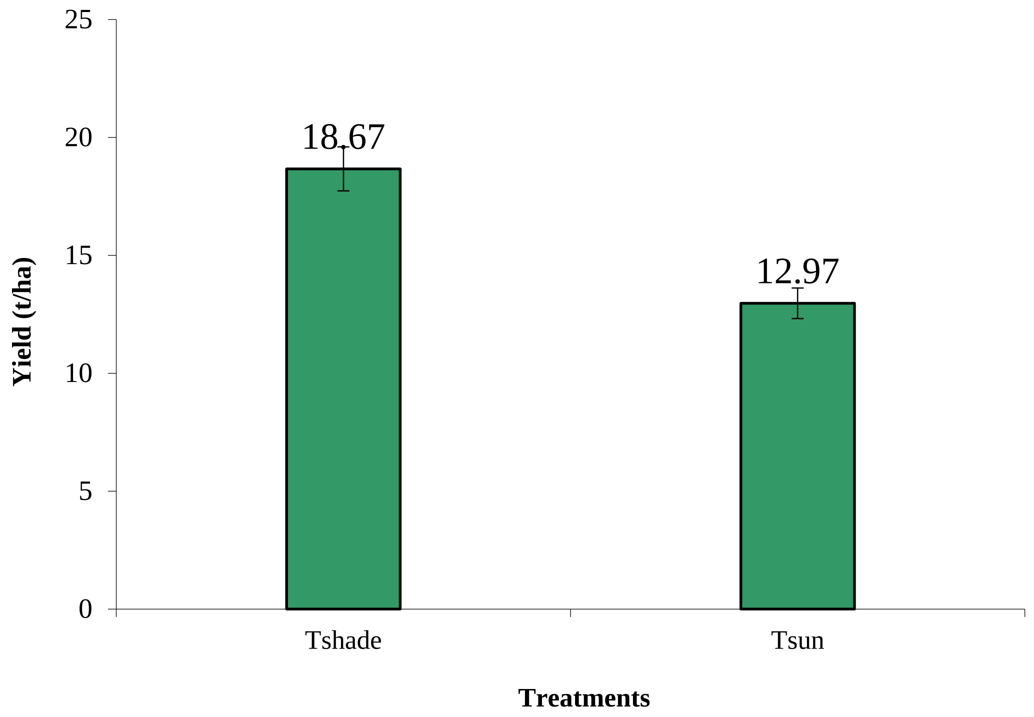

Figure 7: Yield of Kangkong at shade and sun condition

Plate 3: Kangkong plants growing under shade condition

4.2.4 OKRA

Plant height

Plant height of Okra grown under shade level was influenced significantly (Table 5). The plant height increased remarkably with increasing shaded condition. In 100% sunlight plant height was 74.34 cm whereas in shade condition (T_{shade}) it was increased to 112.37 cm. This was probably due to higher apical dominance under shade condition (Hillman, 1984). Similar to this crop higher plant height under reduced light levels was observed in mungbean (Islam, 1996) and in chickpea (Murshed, 1996). This may be attributed due to the stimulation of cellular expansion and cell division under shaded condition (Schoch, 1972). The increase in plant height with corresponding increase of plant population was due to the less light penetration through the canopy which was also reported by Fawusi (1985). The crop in open field has received more light than the shade treatment and eventually the plant remained shorter than that of reduced light condition treatment. Increased plant height due to the effect of polythene shade was reported in maize by lzakobic (1989) and Duhr and Dubas (1990).

Number of leaves per plant

Total number of leaves per plant of Okra was also significantly influenced by reduced light level (Table 5). This parameter showed a similar trend to that of plant height as it increased with reduced light level. The higher number (28.12) of leaves per plant was seen in shade compared to that of control condition (22.33). But more reduction of light e.g; 25% PAR or less is very harmful for leaf production. Hanif *et al*. (2010) found number of leaves was greater in sole crops because of vigorous growth and plenty of food materials production & uptake in their experiment. They also stated that increased plant density (multistoried) was found to reduce leaf number & thereby leaf area per plant. (Muoneke and Udeogalanya, 1991). Similar result was also found by Wadud (1999) in case of okra.

Number of branch

Reduced light level had significant effect on the number of branch per plant, where the higher number of branches (10.00) was recorded under full sunlight level compared to that of shaded condition (7.75). The lower number of branches under shaded condition might be due to higher auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches.

Plant diameter

Plant stem base diameter is the indicator of healthy plant on which yield is dependent. Plant base diameter of Okra was significantly influenced by reduced light level (Table 5). Plant base diameter of Okra grown under full sun under the treatment T_{sun} was recorded as 17.62 mm but increased remarkably (21.16 mm) when grown under reduced light level.

Leaf Chlorophyll Content

Leaf chlorophyll content of Okra was noticeably lower (52.37 SPAD unit) in reduced light level than that of sunlight condition (58.33 SPAD unit).

Height from base to crown (cm)

Height from base to crown was significantly influenced in case of Okra by reduced light level (Table 5 and Appendix VII). Highest height to base of crown (52.03 cm) was observed under shade condition under the treatment T_{shade}, while the lowest height to base of crown (36.01 cm) was seen in full sunlight condition under the treatment T_{sun}.

Width of crown (cm)

Reduced light level had highly significant influence on the width of crown of Okra. From the Table 5 it was found that the highest width of crown (83.00 cm) was found in reduced light or shade condition under the treatment T_{shade} and lowest (62.55 cm) in open field (T_{sun}) condition .

No of flower cluster/ plant

Number of Okra flower cluster per plant was recorded as significant in shade condition under the treatment T_{shade} compared to full sunlight (T_{sun}). From the table it was noted that in treatment T_{shade} maximum number (9.79) of flower clusters were recorded and in full sunlight or in treatment T_{sun} it was recorded as 7.49.

No of fruits/ plant

The highest number of fruits per plant (25.53) was produced when okra grown in reduced light level under the treatment T_{sun}, which was significantly higher compared to the lowest number of fruits per plant (20.81) produced under treatment T_{shade} (Appendix VII and Table4). Rahman (2005) conducted an experiment on okra under different colored polythene shades and found maximum number of fruits per plant under red colored polythene shade. This present investigation was supported by Aldazabal and Zamora (2000).

Single fruit weight (g)

Single fruit weight respond significantly with the reduced light level as it was recorded as 30.04 gm and 25.87 gm under treatment T_{shade} and treatment T_{sun} respectively.

Single fruit length (cm)

Reduced light level had significant influence on the single fruit length of Okra. From the Table it was found that the highest single fruit length (18.72 cm) was found in reduced light level- shade condition under the treatment T_{shade} and lowest (14.73 cm) in open field (T_{sun}) condition .

Single fruit girth (cm)

Different light levels significantly influenced the single fruit girth. The highest girth of individual fruit (4.61cm) was produced in full PAR condition under the treatment (T_{sun}) and the lowest single fruit girth (4.41) was recorded under the treatment T_{shade} in reduced light. Hanif *et al*. (2010) stated that the lower fruit girth under heavy shade may be associated with the lower mobilization of reserve iassimilation to reproductive organ. Similar finding in case of okra and eggplant was also reported by Wadud (1999) and Rahman (2006), respectively.

Yield per plot and per hectare

It was observed that there were significant difference in respect of yields per plot and per hectare of Okra by the reduced light level (Appendix VII). The highest yield per plot (11.25 kg) was found when Okra grown under reduced sun condition (T_{shade}). On the other hand, the lowest yield per plot (10.71 kg) was recorded when Okra was cultivated under full sun condition (T_{sun}). (Table 5 and Appendix VII). The highest yield per hectare (22.54 ton) was found when Okra grown under reduced sunlight condition (T_{shade}). On the other hand, the lowest yield per plot (21.42 ton) was recorded when Okra was cultivated under full sun condition (T_{sun}). (Table 5 and Appendix VII).

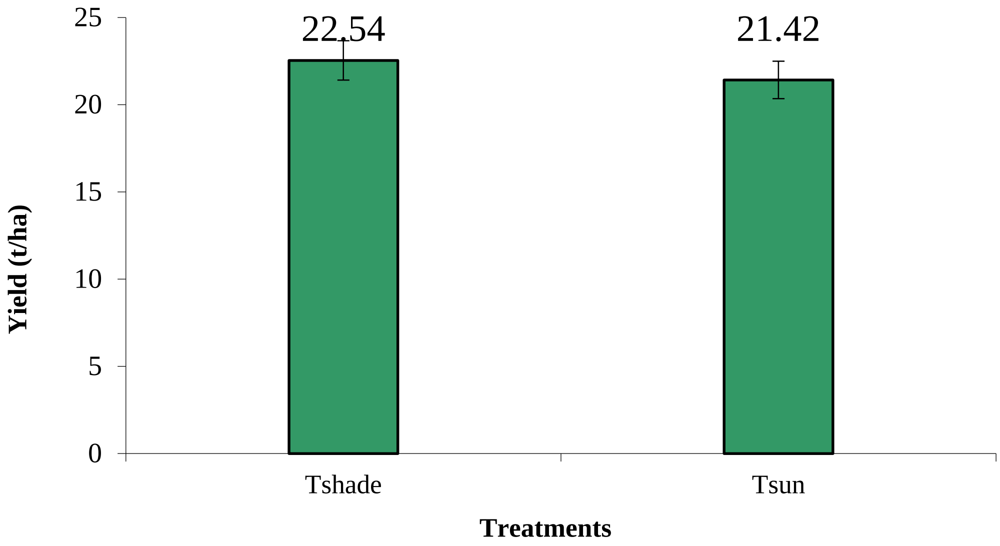

Figure 8: Yield of Okra at shade and sunlight levels

Plate 4 : Okra plants growing under shade condition

Table 5. Growth and yield contributing characters of Okra under control (full sunlight) and under reduced light intensity based agroforestry system

Treatment combination	Plant height (cm)	No. of leaves/ plant	No. of branch/ plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (gm)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
T_{shade}	**112.37**	**28.12**	**7.75**	**21.16**	**52.87**	**52.03**	**83.00**	**9.79**	**25.53**	**30.04**	**18.72**	**4.41**	**11.25**	**22.54**
T_{sun}	**74.34**	**22.33**	**10.00**	**17.62**	**58.33**	**36.01**	**62.55**	**7.49**	**20.81**	**25.87**	**14.73**	**4.61**	**10.71**	**21.42**
CV%	3.56	2.79	3.11	3.39	1.12	4.87	3.89	5.03	3.18	2.06	6.36	0.63	1.40	0.29
$LSD_{0.05}$	11.67	2.48	0.97	2.31	2.19	7.53	9.94	1.53	2.60	1.99	3.74	0.11	0.56	0.22
$LSD_{0.01}$	26.93	5.71	2.23	5.33	5.05	17.36	22.92	3.52	5.99	4.58	8.62	0.26	1.23	0.51
Level of significance	**	**	**	*	**	**	**	*	**	**	*	**	**	**

T_{sun} = Planting summer vegetables under full sunlight (control)
T_{shade} = Planting summer vegetables under reduced light intensity
* = 5% level of significance
** = 1 % level of significance

Table 6. Growth and yield contributing characters of Eggplant under control (full sunlight) and under reduced light intensity

Treatment combination	Plant height (cm)	No. of leaves/ plant	No. of branch/ plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (gm)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
T_{shade}	**65.44**	**71.89**	**10.03**	**13.21**	**55.60**	**34.08**	**61.42**	**6.52**	**4.54**	**66.25**	**16.33**	**2.72**	**8.20**	**16.07**
T_{sun}	**54.89**	**105.63**	**13.20**	**14.30**	**47.53**	**32.10**	**48.19**	**12.73**	**9.52**	**78.87**	**21.14**	**3.17**	**11.35**	**22.63**
CV (%)	1.50	3.65	4.33	1.29	0.42	0.20	0.70	6.69	2.01	1.12	4.62	3.55	2.20	0.32
$LSD_{0.05}$	3.18	11.38	1.75	0.63	0.76	0.22	1.34	2.26	0.50	2.85	3.03	0.37	0.75	0.22
$LSD_{0.01}$	7.32	26.26	4.03	1.45	1.76	0.51	3.10	5.22	1.15	6.56	7.00	0.85	1.74	0.51
Level of significance	**	**	**	**	**	**	**	**	**	**	*	*	**	**

T_{sun} = Planting summer vegetables under full sunlight (control)
T_{shade} = Planting summer vegetables under reduced light intensity

* = 5% level of significance
** = 1 % level of significance

4.2.5 EGGPLANT

Plant height

Plant height of Eggplant grown under reduced light level was influenced significantly (Table 6). The plant height increased with increasing shade level. In 100% sunlight plant height was 54.89 cm whereas in shade condition it was increased to 65.44 cm. It supported the findings of Hillman, 1984.

Number of leaves per plant

Total number of leaves per plant of eggplant was also significantly influenced by reduced light level (Table 6). This parameter showed a reverse trend that plant height as it increased with increased percent of light level. The higher number (105.63) of leaves per plant was seen in sunlight compared to that of shade condition (71.89). This might be due to higher sunlight was absorbed in full light so greater number of leaves were produced.

Number of branches per plant

Reduced light levels had significant effect on the number of branch per plant, where the higher number of branches (13.20) was recorded under 100% light level under treatment T_{sun} compared to that of shaded condition (10.03). The lower number of branches under shaded condition might be due to higher Auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah *et al*., 1999).

Plant diameter

Plant base diameter of eggplant was significantly influenced by shade level (Table 6). Plant base diameter of eggplant grown under full sun was recorded as 14.30 mm but decreased when grown under reduced light level (13.21mm).

Leaf chlorophyll content

Leaf chlorophyll content of eggplant was significantly higher (55.60 SPAD unit) in reduced light level than that of full sunlight condition (47.53 SPAD unit).

Height from base to crown (cm)

Crown height of eggplant was slightly influenced by reduced light level (table 6). Under full sun it was recorded as 32.10 cm and increased when grown under reduced light level (34.08 cm).

Width of crown (cm)

Varying crown width was resulted due to different level of light. In 100% light condition it was observed as 48.19 cm which was increased (61.42 cm) at reduced light condition.

No of flower cluster/ plant

Number of eggplant flower cluster was increased in full sunlight condition (12.73) compared to shade condition (6.52).

No of fruits/ plant

The most impressive contribution to fruit yield of eggplant is the number of edible fruit per plant. Light levels had significant influence on the number of fruit per plant of eggplant (Table 6). Sunlight (100% light) produced the higher number (9.52) of fruits per plant than shade (4.54). 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, 1997).

Single fruit weight (g)

Weight of single fruit of eggplant varied significantly irrespective of light levels. Single fruit weight was increased (78.87 g) at full level of light, where decreased (66.25g) in shaded condition.

Single fruit length (cm)

Under shade level, length of single fruit was lower (16.33 cm) than full sunlight condition (21.14 cm). The present results are in support of Rahman

(2006) who found the highest number of fruits per plant in open field when eggplant grown as agroforestry system.

Single fruit girth (cm)

Girth of fruit of eggplant varieties varied significantly irrespective light levels. The fruit girth decreased with the decrease of light level. In 100% sunlight girth was 3.17 cm where 2.72 cm was found in shaded condition. The lower fruit girth under heavy shade may be associated with the lower mobilization of reserve assimilation to reproductive organ. Similar finding in case of eggplant was reported by Wadud (1999) and Rahman (2006), respectively.

Yield per plot and per hectare

It was observed that there were significant variations in respect of yields per plot and per hectare of eggplant by the reduced light level (Appendix VIII). The highest yield per plot (11.35 kg) and yield per hectare (22.63t) were found when in eggplant grown under full sunlight condition (T_{sun}). On the other hand, the lowest yield per plot (8.20 kg) and yield per hectare (16.07 t) were recorded when Indian spinach was cultivated under shade condition (T_{shade}) (Table 6 and Appendix VIII).

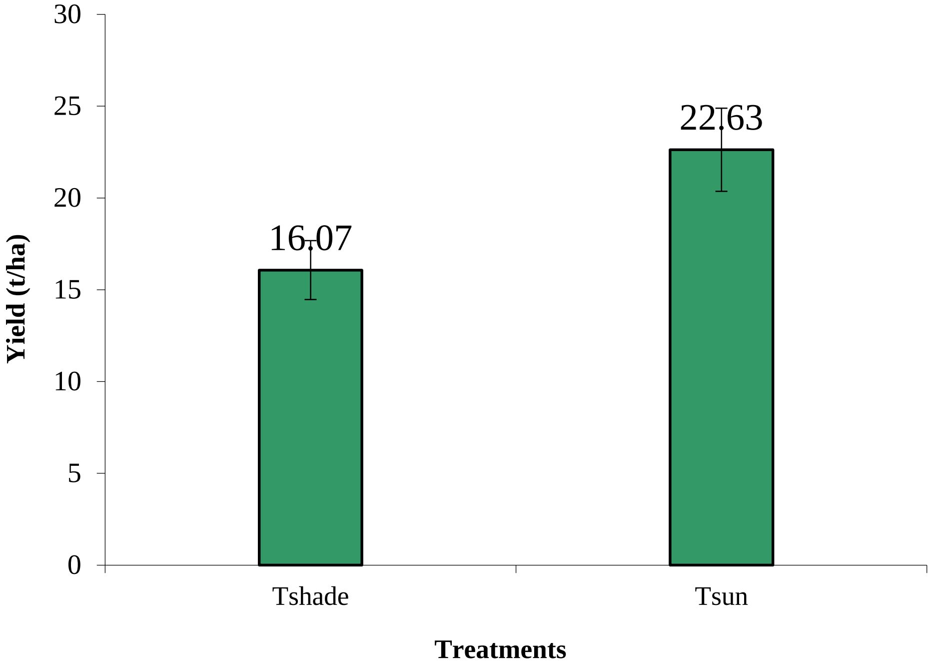

Figure 9: Yield of Eggplant at shade and sunlight levels

Plate 5: Eggplant with flower and fruit in full sun level

4.2.6 CHILLI

Plant height

Plant height of Chilli grown under different light levels was influenced significantly (Table 7). The plant height increased drastically with full sunlight level. In 100% sunlight, plant height was 70.70 cm whereas in shade condition it was decreased to 64.65cm.

Leaf number

Total number of leaves per plant of Chilli was also significantly influenced by reduced light level (Table 7). The higher number (423.13) of leaves per plant was seen in sunlight compared to that of shade condition (370.67). This might be due to higher sunlight was absorbed in full PAR so greater number of leaves were produced.

Number of branches per plant

Different light levels had different effects on the number of branch per plant, where the higher number of branches was recorded under 100% light level (12.05) compared to that of shaded condition (6.05). The lower number of branches under shaded condition might be due to higher auxin production in plant grown under shaded condition which ultimately suppressed the growth of lateral branches (Miah et al., 1999).

Plant diameter

Plant base diameter of Chilli was significantly influenced by shade level (Table 7). Plant base diameter of Chilli grown under full light was recorded as 11.39 mm but decreased when grown under reduced PAR level (9.94 mm).

Table 7. Growth and yield contributing characters of Chilli under control (full sunlight) and under reduced light intensity

Treatment combination	Plant height (cm)	No. of leaves/ plant	No. of branch/ plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (gm)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
T_{shade}	**64.65**	**370.67**	**6.05**	**9.94**	**73.63**	**36.37**	**42.34**	**17.50**	**16.04**	**0.96**	**4.73**	**0.45**	**0.60**	**5.41**
T_{sun}	**70.70**	**423.13**	**12.05**	**11.39**	**76.23**	**34.03**	**45.43**	**32.88**	**31.15**	**1.32**	**6.03**	**0.62**	**0.87**	**8.06**
CV (%)	0.93	0.22	1.79	2.33	0.49	0.24	0.37	1.29	0.15	10.29	7.08	8.25	89.77	1.51
$LSD_{0.05}$	2.21	3.03	0.57	0.87	1.29	0.29	0.58	1.14	0.11	0.42	1.34	0.16	0.11	0.35
$LSD_{0.01}$	5.09	6.98	1.31	2.02	2.97	0.68	1.33	2.63	0.26	0.96	3.09	0.36	0.26	0.81
Level of significance	**	**	**	**	**	**	**	**	**	NS	NS	*	**	**

T_{sun} = Planting summer vegetables under full sunlight (control)
T_{shade} = Planting summer vegetables under reduced light intensity

** = 1 % level of significance
* = 5 % level of significance

Leaf chlorophyll content

Leaf chlorophyll content of chilli was higher (76.23 SPAD unit) in full light (T_{sun}) level than that of shade condition (T_{shade}) 73.63 SPAD unit. This may be due to in shaded condition leaves were more green for a longer period of time than full sunlight condition. In full sunlight leaves were thrived in more light so they were yellowed.

Height from base to crown (cm)

Height to base of crown was significantly influenced in case of chilli by shade level (Table 7 and Appendix). Highest height from base to crown (36.37 cm) was observed under shade condition under the treatment $T_{shade,}$ while the lowest height from base to crown (34.03cm) was seen in full sunlight condition under the treatment T_{sun}.

Width of crown (cm)

Reduced light level had significant influence on the width of crown of chilli. From the Table 7, it was found that the lowest (42.34 cm) width of crown was found in T_{shade} condition and highest (45.43 cm) in open field condition (T_{sun}).

No. of flower cluster/ plant

Number of flower cluster/plant significantly influenced in case of chilli by reduced light level (Table 7 and Appendix IX). Highest height to base of crown (32.88) was observed under full sunlight condition under the treatment T_{sun} while the lowest height to base of crown (17.5) was seen in shade condition under the treatment $T_{shade..}$

Single fruit weight (g)

Single fruit weight did not respond significantly as the highest weight (1.32 gm) of single fruit was reported in full sunlight, where in reduced light intensity, lowest (0.96 gm).

Single fruit length (cm)

Under reduced light level length of single fruit was lower (4.73 cm) than full sunlight condition (6.03 cm) and this was insignificant.

Single fruit girth (cm)

Girth of fruit of chilli varieties varied significantly in reduced light level. The fruit girth decreased with the decrease of light level. In 100% sunlight girth was 0.62 cm where 0.45 cm was found in shaded condition.

Yield per plot and per hectare

It was reported that there were significant variations in respect of yields per plot and per hectare of Chilli by the reduced light level (Appendix IX). The highest yield per plot (0.87 kg) and yield per hectare (8.06 t) were found when chilli plants grown under full sunlight condition (T_{sun}). On the other hand, the lowest yield per plot (0.60 kg) and yield per hectare (5.41 t) were recorded when Chilli was cultivated under shade condition (T_{shade}) (Table 7 and Appendix IX).

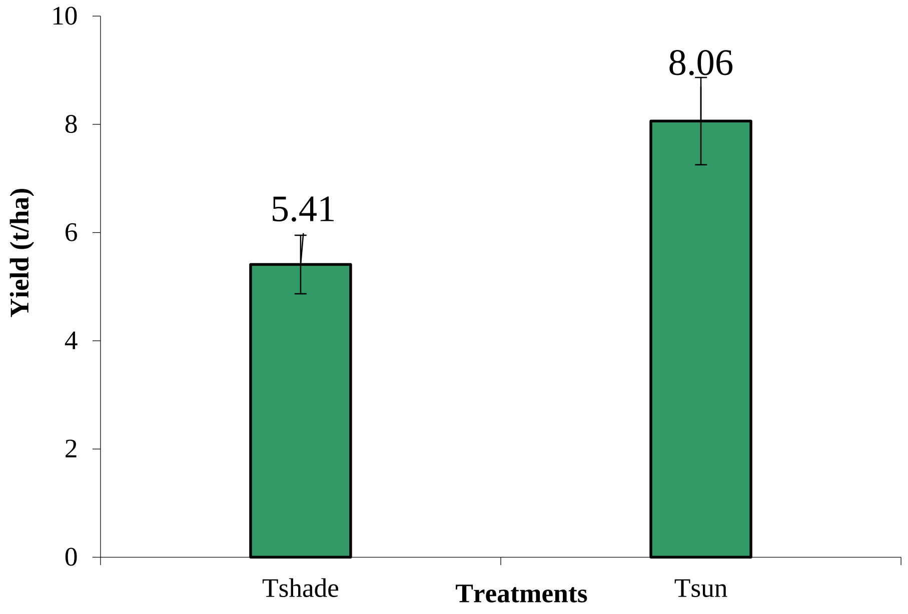

Figure 10: Yield of Chilli at shade and sunlight levels

Plate 6: Chilli plant with flower at full light level

5. **Comparative yield performance of six summer vegetables under reduced light and sunlight condition**

In figure 11, comparative yield performance of summer vegetables under reduced light and sunlight condition was shown. From the figure, it is clear that among leafy vegetables Kangkong gave the highest yield (18.67 ton/ha) in the shade condition. Among fruit vegetables Okra gave the highest yield (21.42 ton/ha) in shade treatment. Stem amaranth showed promising result both in sunlight (27.67 ton/ha) and shade (25.77 ton/ha) condition but was insignificant. Eggplant yield was so much higher (22.63 ton/ha) in sunlight. Yield of Indian spinach (5.67 ton/ha) and Chilli (5.41 ton/ha) was significantly similar under shade level. So, Kangkong and Okra under agroforestry systems allowing reduced light intensity might be encouraged in rural Bangladesh.

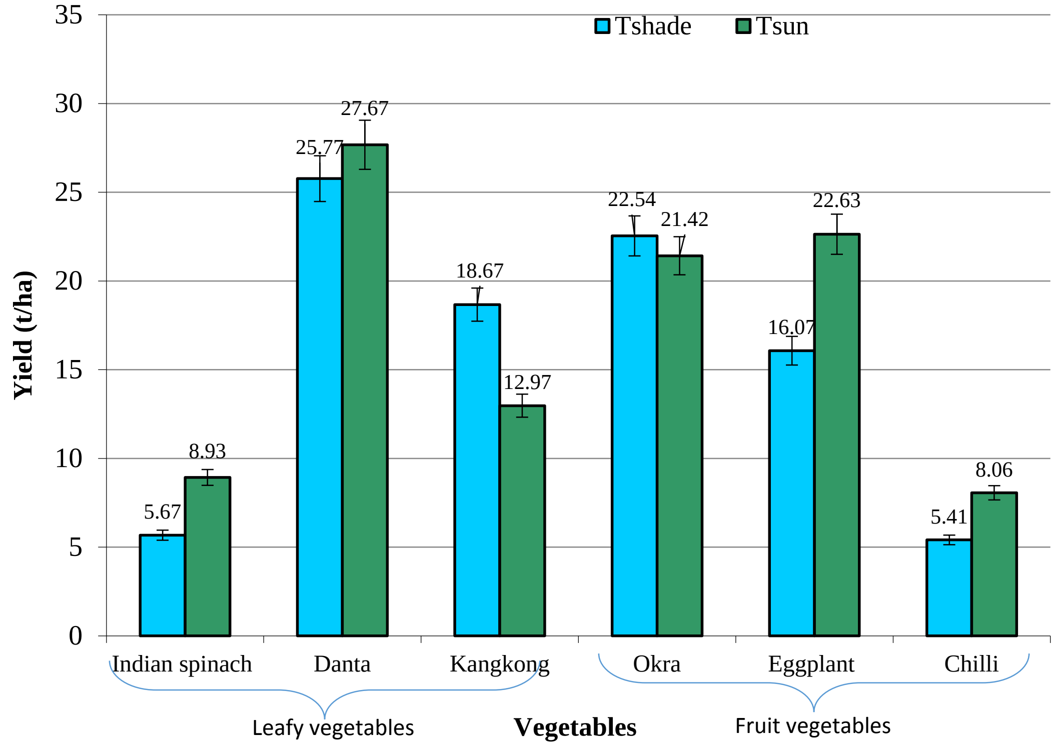

Figure 11: Comparative yield performance of six summer vegetables under reduced light and sunlight condition

CHAPTER V
SUMMARY AND CONCLUSION

Bangladesh is struggling to provide the national demand of food, fuel as well as to solve the malnutrition problem due to overcrowded condition with geometrical population growth rate. Agroforestry system is one of the diversification systems that can balance this problem by maximum utilization of homesteads and other shaded places of the country. The experiment was conducted to screen of some higher yielding and partial shade tolerant summer vegetables under reduced light based agroforestry system during the period from March to June, 2014 at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka. The six summer vegetables such as Indian Spinach, Danta, Kangkong, Okra, Eggplant, Chilli were grown under (i) open field condition and (ii) partial shaded condition (reduced light intensity which was created by using dark coffee colored mosquito net.), following the single factor Randomized Complete Block Design (RCBD) with three replications.

The actual light intensities inside the net as well as open condition were recorded and the maximum average light intensity reduction (%) was found in case of Chilli (42.2%) and minimum average light intensity reduction (%) was observed in case of Indian Spinach (22%) in shade. In case of Eggplant, Kangkong, Stem Amaranth and Okra light intensity reduction was 25.42%, 28.41% 29.9% and 39.9% respectively. During the study period soil temperature and moisture were also recorded. The Highest soil temperature was recorded in April-35.7˚C in sun and 34.2˚C in shade while the highest soil moisture was recorded in June both in open and shade as 39.3% and 28.5% respectably.

Performances of six summer vegetables under reduced light are summarized below:

In case of Indian spinach plants, all the selected parameters except height from base to crown showed significant difference in reduced light level. Morphological behaviors such as plant height (56.28 cm), chlorophyll content of leaves (52.37 SPAD unit), width of crown (42.58 cm) were gradually increased with the increase of shade level. But number of leaves per plant (215.00), number of branches per plant (7.62), plant base diameter (18.00 mm), yield per plot (4.47 kg) and per hectare yield (8.93 t) were found progressively increased under open field condition.

Morphological characters like plant height (109.11 cm) and leaf chlorophyll content (55.00 SPAD unit) of Stem amaranth (Danta) were found maximum under reduced light intensity level. On the other hand, number of leaves per plant (114.00), branches per plant (23.44), plant diameter (35.23 mm), height from base to crown (51.39 cm) and width of crown per plant (48.83 cm) were found maximum under full sunlight condition but yield per plot and yield per hectare were not found significant under reduced light level.

In case of Kangkong, all the selected parameters in respect of growth and yield showed significant difference when cultivated under reduced light except number of leaves per plant. Morphological behaviors such as plant height (61.50 cm), plant diameter (10.60 mm), chlorophyll content of leaves (46.93 SPAD unit), height to base of crown (23.34 cm), width of crown (76.15 cm), yields per plot (9.33 kg), and per hectare (18.67 t) were found progressively increased under shade condition. But number of branches per plant (21.44) were found the highest in open field condition.

Significant difference on yield and yield contributing characters were also recorded in Okra. However, highest plant height (112.37 cm), plant diameter (21.16 mm), height from base to crown (52.03 cm), width of crown (83.00 cm), number of flower cluster per plant (9.79), number of fruits per plant (25.53), single fruit weight (30.04 gm), single fruit length (18.72 cm), yield per plot (11.25 kg) and yield per hectare (22.54 ton/ha) were observed under treatment T_{shade}. While the lowest values were recorded under full sunlight. Moreover, maximum number of branches per plant (10.00), leaf chlorophyll content (58.33 SPAD unit), single fruit girth (4.61cm), were found under the treatment T_{sun} (open field condition).

In Eggplant, all the selected parameters were significant when grown under two different treatments. The growth and yield characteristics of Eggplants were influenced significantly by the reduced light level. The tallest plant height (65.44cm), chlorophyll content (55.60 SPAD unit), height from base to crown (34.08 cm) and width of crown (61.42 cm) were recorded under reduced light level (T_{shade}). Whereas maximum number of leaves per plant (105.63), number of branches per plant (13.20), plant diameter (14.30 mm), number of flower cluster per plant (12.73), number of fruits per plant (9.52), single fruit weight (78.87 g), single fruit length (21.14 cm), single fruit girth (3.17cm), yield per plot (11.35 kg) and per hectare (22.63 t) were observed under full sunlight level (T_{sun}).

All the selected characteristics related to the performance of chilli showed significant difference under reduced light level except single fruit weight and single fruit length. The maximum length of plant (70.70 cm) ,number of leaves per plant (423.23), maximum number of branches per plant (12.50), plant diameter (11.39 mm), chlorophyll content (76.23 SPAD unit), width of crown (45.43 cm), number of flower cluster per plant (32.88), number of fruits per plant (31.15), single fruit girth (0.62m), yield per plot (0.87 kg) and per hectare (8.06 t) were measured under full sunlight condition (T_{sun}), whereas minimum were found under full shade condition (T_{shade}).

Conclusion

From the experiment it is clear that among leafy vegetables Kangkong gave the highest yield in the shade condition. Among fruit vegetables Okra gave the highest yield in shade treatment. Stem amaranth showed promising result both in sunlight and shade condition but was insignificant. So, Kangkong and Okra should be encouraged to cultivate under reduced light levels as agroforestry systems. Further studies are suggested at different regions of Bangladesh to evaluate the compatible vegetable production under reduced light conditions for regional adaptability.

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APPENDICES

Appendix I: Characteristics of soil experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Central Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and Chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Khatun, 2014

Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from March to June, 2014

Month (2014)	*Air temperature (˚C)		* Relative humidity (%)	* Total rainfall (mm)
	Maximum	Minimum		
March	34.2	23.4	61	112
April	34.7	25.9	70	185
May	35.4	22.5	80	577
June	36.0	24.6	83	563

*Monthly average

*Source: Bangladesh Meteorological Department (Climate & weather division) Agargaon,Dhaka-1212

Appendix III: Layout of the experimental field

V_1= Indian Spinach

V_2= Danta (Stem Amaranth)

V_3= Kangkong

V_4= Okra

V_5= Eggplant

V_6 = Chill

R_1= Replication 1; R_2= Replication 2; R_3= Replication 3.

- Dark colored plots are under shade treatment

Appendix IV. Analysis of variance (ANOVA) of Growth and yield contributing characters of Indian spinach under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	Df	Plant height (cm)	No. of leaves/ plant	No. of branch/plant	Plant diameter (cm)	Leaf chlorophyll (SPAD)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ ha)
Replication	2	3.67	46.82	0.013	0.405	1.766	0.141	3.443	0.092	1.500
Treatment	1	158.51**	16286.46**	2.419**	9.004*	203.234**	0.522NS	510.604**	4.034*	15.941*
Error	2	1.95	20.42	0.022	0.405	1.766	0.163	1.703	0.139	0.500

T_{sun} = Planting summer vegetables under full sunlight (control)

T_{shade} = Planting summer vegetables under reduced light intensity

** = Significant at 1% level of probability

* = Significant at 5% level of probability

NS = Not significant

Appendix V. Analysis of Variance (ANOVA) of Growth and yield contributing characters of Danta under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	Df	Plant height (cm)	No. of leaves/ plant	No. of branch/plant	Plant diameter (mm)	Leaf chlorophyll (SPAD)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
Replication	2	42.163	6.22	0.461	4.181	2.00	1.576	0.395	0.008	0.515
Treatment	1	1366.550*	1320.46**	29.040**	150.300*	124.21*	41.501*	25.585*	1.354**	5.415NS
Error	2	35.943	11.54	0.541	4.871	6.00	1.576	1.095	0.004	0.515

T_{sun} = Planting summer vegetables under full sunlight (control)
T_{shade} = Planting summer vegetables under reduced light intensity

Appendix VI. Analysis of Variance (ANOVA) of Growth and yield contributing characters of Kangkong under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	df	Plant height (cm)	No. of leaves/ plant	No. of branch/plant	Plant diameter (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	Yield (kg/plot)	Yield (ton/ha)
Replication	2	0.889	6.500	0.112	0.155	0.263	0.195	0.51	0.242	0.420
Treatment	1	151.504**	0.034NS	17.750**	12.098**	14.978*	72.662**	545.49**	12.269**	48.735**
Error	2	1.564	10.500	0.332	0.215	0.340	0.065	0.67	0.087	0.620

T_{sun} = Planting summer vegetables under full sunlight (control)

T_{shade} = Planting summer vegetables under reduced light intensity

Appendix VII. Analysis of Variance (ANOVA) of Growth and yield contributing characters of Okra under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	df	Plant height (cm)	No. of leaves / plant	No. of branch/ plant	Plant diam. (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (gm)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
Replication	2	4.30	0.866	0.026	0.593	0.719	0.530	0.000	0.091	0.547	0.720	0.401	0.001	0.049	0.001
Treatment	1	2169.42**	50.286**	7.594**	18.797*	44.717**	384.961**	627.304**	7.935*	35.966**	2.053NS	23.880*	0.060**	0.437*	0.073*
Error	2	11.04	0.497	0.076	0.433	0.389	4.590	8.000	0.189	0.547	0.320	1.131	0.001	0.023	0.004

T_{sun} = Planting summer vegetables under full sunlight (control)

T_{shade} = Planting summer vegetables under reduced light intensity

Appendix VIII: Analysis of Variance (ANOVA) of Growth and yield contributing characters of Eggplant under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	df	Plant height (cm)	No. of leaves/ plant	No. of branch/ plant	Plant diam. (mm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (gm)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
Replication	2	2.257	6.50	0.207	0.062	0.107	0.012	0.066	0.615	0.020	1.906	0.370	0.028	0.116	0.002
Treatment	1	166.95**	1707.58**	17.716**	1.675**	98.496**	5.881**	262.549**	57.908**	37.201**	238.897**	33.37*	0.304*	14.884**	64.550*
Error	2	0.817	10.50	0.247	0.032	0.047	0.004	0.146	0.415	0.020	0.656	0.746	0.011	0.046	0.004

T_{sun} = Planting summer vegetables under full sunlight (control)

T_{shade} = Planting summer vegetables under reduced light intensity

Appendix IX. Analysis of Variance (ANOVA) of Growth and yield contributing characters of Chilli under control (full sunlight) and under reduced light intensity based agroforestry system.

Source of variation	df	Plant height (cm)	No. of leaves/ plant	No. of branch/ plant	Plant diam. (cm)	Leaf chlorophyll (SPAD unit)	Height from base to crown (cm)	Width of crown (cm)	No. of flower cluster/ plant	No. of fruits/ plant	Single fruit weight (g)	Single fruit length (cm)	Single fruit girth (cm)	Yield (kg/plot)	Yield (ton/ha)
Replication	2	1.095	3.262	0.016	0.101	0.042	0.004	0.027	0.155	0.061	0.008	0.101	0.001	0.001	0.004
Treatment	1	54.904**	4154.349**	54.000**	3.154**	10.402**	8.213**	13.711**	354.817**	342.468**	0.173 NS	2.535 NS	0.043*	0.099**	10.507**
Error	2	0.395	0.742	0.026	0.062	0.134	0.007	0.027	0.105	0.001	0.014	0.145	0.002	0.001	0.010

T_{sun} = Planting summer vegetables under full sunlight (control)

T_{shade} = Planting summer vegetables under reduced light intensity