SCREENING OF LEAFY VEGETABLES UNDER MAHOGANY TREE (*Swietenia mahagoni*) BASED AGROFORESTRY SYSTEM

TANJILAL AZIZ

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2014

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BY

TANJILAL AZIZ

REG. NO. : 07-02521

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SEMESTER: JANUARY-JUNE, 2014

APPROVED BY:

Prof. Dr. Md. Forhad Hossain
Supervisor

Dr. Ferzana Islam
Associate Professor
Co-Supervisor

Dr. Nazmun Naher
Chairman
Examination Committee

DEPARTMENT OF
AGROFORESTRY & ENVIRONMENTAL SCIENCE
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled ***"SCREENING OF LEAFY VEGETABLES UNDER MAHOGANY TREE (Swietenia mahagoni) BASED AGROFORESTRY SYSTEM"*** *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* ***TANJILAL AZIZ, Registration no. 07-02521*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2014
Place: Dhaka, Bangladesh

Prof. Dr. Md. Forhad Hossain
Supervisor
Department of Agroforestry
& Environmental Science
SAU, Dhaka

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Omnipotent Allah, the Supreme Ruler of the universe who enables the author to complete this present piece of work. The author deems it a great pleasure to express her profound gratefulness to her respected parents, who entiled much hardship inspiring for prosecuting her studies, receiving proper education.

The author feels proud to express her heartiest sence of gratitude, sincere appreciation and immense indebtedness to her supervisor Prof. Dr. Md. Forhad Hossain, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of thesis. Without his intense co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor Dr. Ferzana Islam, Asiciate Professor, Department of Agroforestry and Environmental Science, SAU, Dhaka, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

The author expresses her sincere respect and sence of gratitude to Chairman Dr. Nazmun Naher, Professor, Departement of Agroforestry and Environmental Science, SAU, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses her heartfelt thanks to all the teachers of the Department of Agroforestry and Environmental Science, SAU, for their valuable teaching, suggestions and encouragement during the period of the study.

The author expresses her sincere appreciation to her colleages, relatives (Dr. Md. Samiul Islam), well wishers and friends (Mominul Haque) for their inspiration, help and encouragement throughout the study.

The Author

Title: SCREENING OF LEAFY VEGETABLES UNDER MAHOGANY TREE (*Swietenia mahagoni*) BASED AGROFORESTRY SYSTEM

ABSTRACT

The experiment was conducted at Central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to screening of some leafy vegetables under mahogany tree based agroforestry system. In this study the 25 years old previously established mahogany tree were used as tree components. As leafy vegetable Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were used. The experiment consists of two factors: Factor A: Orientation of planting (2) - O_1: East facing, O_2: West facing; Factor B: Distance of planting (5 levels)- D_0: Planting leafy vegetables under full sunlight, D_1: Planting leafy vegetables 3.5 m apart from mahogany trees, D_2: Planting leafy vegetables 4.0 m apart from mahogany trees, D_3: Planting leafy vegetables 4.5 m apart from mahogany trees and D_4: Planting leafy vegetables 5.0 m apart from mahogany trees. The experiment was conducted with Randomized Complete Block (RCBD) with three replications The result revealed that, due to orientation of planting, in case of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth, the tallest plant,the highest yield and light intensity was recorded from O_1, where light intensity and soil moisture were maximum. Soil temperature was minimum. On the other hand yield of four leafy vegetables were the lowest at west facing (O_2). Light intensity and soil moisture were minimum. Soil temperature was maximum. The yield of four leafy vegetables were the best from 4.5 m apart from Mahogany trees (D_3). On the other hand yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were the lowest from 3.5 m apart from Mahogany trees (D_1). Light intensity was the highest at treatment combination of O_2D_0 and the lowest light intensity was observed at treatment combination of O_2D_2. The yield per hectare (41.22, 44.82, 55.53 and 44.25 ton, respectively) of four leafy vegetables were superior at east facing 4.5 m apart from Mahogany trees (O_1D_3) where, soil moisture was the highest. On an average the lowest yield per hectare (25.13, 26.56, 37.01 and 23.22 ton, respectively) of four leafy vegetables were observed at west facing 3.5 m apart from Mahogany tree line (O_2D_1) where the lowest soil moisture was observed and the soil temperature was comparatively higher.

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CHAPTER I

INTRODUCTION

Bangladesh is a thickly populated small country with an area of 147,570 $km^2$and the population of the country is 152.25million (BBS, 2013). The country has a land area of 14.39 million hectares and per capita land area is decreasing at an alarming rate of 0.005 ha/capita/year since 1989 (Hossain and Bari, 1996). As a result, there is a tremendous pressure on the natural resources of the country. Considering the two dominant development paths, rapid economic growth through industrialization and agriculture, forests are continuously deleted at an alarming rate. This put heavy pressure on land for human habitation and crop production. About 31.60% of the gross domestic product of Bangladesh is contributed from agriculture sector (BBS, 2011).Forestry plays an important role in maintaining environmental equilibrium and socio-economic implementation of the people. A country needs 25% of forest land of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is endowed with only 17% of unevenly distributed forests (BBS, 2013). Substantial depletion of forest resources has occurred in the last few decades and now it is reduced to less than 0.02 ha per person, one of the lowest ratios in the world (BBS, 2013). Under these alarming situations, agricultural production as well as forest resources must be increased by using modern or new techniques.

Agroforestry is considered as one of the new and sustainable techniques which is useful for ecological balance as well as ensure dietary materials. Agroforestry is an age old practice in Bangladesh, further development may be brought for harvesting maximum benefit by identification of appropriate tree-crop combination. Agroforestry, the integration of the tree, crop and vegetable on the same area of land is a promising production system for maximizing yield (Nair, 1990) and maintaining friendly environment. Growing of crops/vegetables in association with trees is becoming popular day by day for higher productivity, versatile/multipurpose use and environmental consciousness among the peoples

(Sheikh and Khaleque, 1982). Forestry with agricultural crop can provide a sound ecological basis for increased crop and forest productivity, more dependable economic returns, and greater diversity in social benefits on a sustained basis (Rahim, 1997; Franis, 2001). Lundgren and Raintree (1982) stated that agroforestry is a collective name for all land use systems and technologies where woody perennials are deliberately used on the same land management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. So, this practice can address the forest scarcity as well as the demand of agricultural production.

In Bangladesh Kalmi, Red Amaranth, Indian spinach, Stem amaranth are some of the important summer vegetables. To meet up farmer's timber and fuel wood demand rural household planted large number of saplings of these species in their cropland, homestead, and other fallow lands at block plantations, strip plantation, woodlot plantation, and scattered plantations (Haque, 1996). For identifying the compatible tree-crop combination, particularly understory species i.e. different crops should be screened out in terms of their adaptability and yield in association with the early stage of tree. Therefore, it is necessary to conduct experiments under different tree crop or vegetables combination for screening of different crops in terms of their growth and yield performance. Considering the aforementioned facts and potentiality, a study was undertaken to fortify the following specific objectives:

i. To characterize the morphological and physiological changes of four leafy vegetables under reduced light intensity created by Mahogany tree based agroforestry system ; and
ii. To evaluate the yield and yield contributing characters of four leafy vegetables under reduced light intensity of Mahogany tree based agroforestry system.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

This research has been undertaken to screening of some leafy vegetables under mahogany trees based agroforestry system. Literatures related to these aspects are very scanty and not conclusive in our country and also in abroad. 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-

Concept of Agroforestry

Recently, International Centre for Research in Agroforestry (ICRAF,2006) 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."

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. Aagroforestry 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.

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.

Characteristics of Tree Species in Agroforestry Systems

Selection of suitable tree species is vital in an agroforestry system. Nair (1980) considered the most choice of suitable plant species that can grow together as important factor in ensuring the sources of agroforestry. Generally in the country, there are several challenges in crop and timber production that need to be overcome in order for forestry and tree related activities to greatly contribute to national development (Okorio *et al.,* 2003). The most appropriate species for this system remains an open question for research. King (1979) listed the characteristics at tree species that should be grown with agricultural crops:

- They should tolerate relatively high incidence of pruning;
- They should have a low crown diameter to bole diameter ratio;
- They should be light branching in their habit;
- They should be tolerant of side shade;
- Their phototaxy should permit penetration of the light of the ground;
- Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to the growth of the annual crop in conjunction with which they are being raised;
- The rate of litter fall and litter decomposition should have positive effect on the soil;
- The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics, which reduce competition for solar energy, nutrient and water;
- Their root system and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crops.

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

- Ease of establishment from seeds or seedlings;
- Rapid growth and high productivity of foliage and wood;
- Limited maximum size (may be optimum in small trees);
- Good cropping ability;
- Effective nutrient recycling abilities specially N_2 fixation;
- Multiple uses: food, feed, fire wood, construction materials and other products and services (shade, shelter etc.);
- Minimal competition with shallow rooted annual crops;
- Small leaflets readily detached when dried and quickly decomposed when used as fertilizer;
- Good tolerance for drought, low fertility and others;
- Freedom from pests and diseases; and
- Ease of control of eventual elimination.

Hegde and MacDicken (1990) pointed out some, criteria for planting trees under the agroforestry system: a) Non-interference with arable crops, b) Easy establishment, c) Fast growth and short gestation period, d) Non-allelopathic effects on arable crops, e) Ability to fix atmospheric nitrogen, f) Easy decomposition of litter, g) Ability to withstand frequent lopping multiple uses and high returns, and h) Ability to generate employment.

However, it is not possible to select having all the above mentioned criteria. Therefore, it is necessary to select which plants have most of the characteristics and are adapted to local soil and environmental condition.

Tree-crop Agroforestry Systems and its Structure

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 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.

Solanki (1998) stated that Agroforestry significantly contribute in increasing fuel wood, fodder, cash income and infrastructure in many developing countries. He also stated that Agroforestry has high potential to simultaneously satisfy three important objectives: (i)From a business point of view, Agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously oil the same land area protecting and stabling the ecosystems, (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer, etc.) and (iii) providing stable employment, improved income and material to rural populations.

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 they found 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.

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.

Above and below ground interactions in alley cropping were critically examined by Singh *et al.*, (1989) who found that growth and yield of crops declined from 15% to 30% than that of sole crops as the distance from the tree rows decreased from 5 m to 0.3 m.

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.

Jiang *et al.*, (1994) reported that tree crown had no significant effect on the number of effective spikelets and grains of wheat but it affected total grain yield and 1000-grain weight, with the size of the effect on crop, depending on the distance from the trees.

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 decreased 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 and reduced chlorophyll content. Stomata density, transpiration rate and photosynthesis rate, yield of peppers decreased with increasing the 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%).

Hocking and Islam (1998) conducted an experiment over a five year period for four crops grown under 17 tree species at 8 x 8 m spacing in wetland rice field and found that all tree species grew well, in rice fields, at rates comparable to their growth in forest plantations. Top and root pruning reduced average tree girths by up to 19% and average tree volume by up to 41% depending on intensity of pruning. The crops monitored were *Oryza sativa, Triticum aestivum*, and *Lens culinaris*. Crop yields under the trees averaged 93% of the corresponding yield outside the tree canopy.

Zheng and Li (1998) reported that, shading decreased dry weight by 30.98 to 74.33% with the smallest effect in cv. 1239-F 2121-0. N case of Tomato in green house showed no effect of shading on specific leaf weight and decreased by up to 40.03% and the leaf area by up to 32.21%. Shading increased plant height decreased plant dry weight at flowering.

Solanki (1998) stated that 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.

Difference 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 notreduce 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). There was a negative correlation (r = -0.77) between light intercepted by the trees and yield of ginger and turmeric.

Onwveme 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 should 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 shading generally 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.

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 dry mass 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 with increasing shade, specific leaf area was increased whereas leaf weight ratio and relative growth rate were 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.

Chipungahelo *et al.,* (2007) reported that leaf morphological characteristics growth and development were influencedby light intensity in case of sweet potato. Specific leaf area values in full light were smaller than those under heavy shade. The light intensitysignificantly increased the cowpea seed yield. In low intensity, pineapple flowered earlier and yielded more than in high intensity.

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.

Basak *et al.*, (2009) reported that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree and the growth characters of *Zylia dolabiformis* tree were higher in association with Soybean than Tomato and Radish.

Bari and Rahim (2009) found that multistrata agroforestry systems (MAF) with different tree spacing had significant influence on the root yield of Carrot. The highest carrot root yield (29.87 t ha^{-1}in 2005 & 29.24 t ha^{-1}in 2006) was recorded under sole cropping which was followed by the wider and intermediate spacing of sissoo - lemon based MAF. The reduction in yield of carrot compared to sole cropping was more at closer spacing of MAF.

Sayed *et al.*, (2009) showed that highest production of vegetables (such as red amaranth, stem amaranth, kalmishak, palangshak and Indian spinach grown under Telsur saplings at different distance) were recorded in control condition (without tree) which was significantly similar with 3 and 4 feet distance from the tree base and the lowest was observed under one feet distance which was almost similar with 2feet distance. The growth characteristics of Telsur was significantly influenced by the vegetables. Khatun *et al.* (2009) showed the similar results were comparable to that of the pure crop. Trees at the density of 200 trees ha^{-1} provided a conducive microenvironment to the intercrops.

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 odorata* was significantly influenced by all the three winter vegetables (red amaranth, stem amaranth & 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.

Monim *et al.*, (2010) reported that monoculture produced 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.

Habib *et al.*, (2012) studied that the performance of summer vegetable in association with *Xylia dolabiformis* tree on summer vegetables. The results showed that the yield of the summer vegetables increased gradually with the increase of planting distance of the tree.

Ahmed (2012) found that the kankong and jute yield were gradually increased with increasing distance from akashmoni tree base. However, the vegetables yield had reduced remarkably at 5feet distant from tree base. Both kankong and jute successfully cultivated along with 2 years old Akashmoni tree without significant yield loss.

Babu (2012) conducted an experiment to study the growth and yield of two winter vegetablesi.e. chilli and sweet gourd under different spacing from Eucalyptus tree, and he found that all the parameters i.e. plant height, diameter, leaf length, leaf diameter, no. of fruits plant^{-1}, yield were increased gradually with increasing distance from Eucalyptus tree. It concluded that boundary plantation of Eucalyptus has negative effect on the growth and yield of chilli and sweet gourd.

Ummah (2012) reported that among the morphological parameters of bottle gourd such as vine length, no. of leaves, no. of fruits, weight of fruits, no. of branch and yield were decreased gradually when distance reduced in association of Mahogoni tree.

Bali (2012) conducted an experiment to study the growth and yield of winter vegetables i.e. okra under different spacing from Lemon and Guava tree, and he found that all the parameters i.e. plant height, leaf length, leaf diameter, number of fruits plant-^{1}, yield were increased gradually with increasing distance from lemon and guava tree.

Rahman (2012) evaluate that the growth performance of two winter crops viz. mustard andsweet gourd grown under 2 years old akashmoni tree saplings of four different distances. The result showed that among the morphological characteristics of winter crops plant height, length of branch, no. of siliqua per branch, length of siliqua, vine length, fruit length, no. of fruit, and fruit diameter increased consistently with the increase of distance from sapling. The growth characteristics of Akashmoni (*Acacia auriculiformis)* significantly influenced by the interaction of the crops.

Anwar (2013) conducted an experiment to study the growth and yield of winter vegetables i.e. bottle gourd under different distance from Mahogoni, Akashmoni and Lambu tree and he found that all the parameters i.e plant height, number of leaves plant^{-1}, branches plant^{-1}, average number of male and female flower plant^{-1}, fruits plant^{-1}, average weight of fruit, length of fruits, girth of fruit, fresh yield, dry yield, yield were increased gradually with increasing distance from Mahogoni, Akashmoni and Lambu tree. The results of the experiment revealed that the yield of bottle gourd was increased gradually with the increase of planting distance from the tree.

Mallick *et al.,* (2013) conducted an experiment to study the growth and yield of strawberry fruit under different distance from lohakat tree and she found that morphological characteristics viz. plant height, no. of leaves per plant, leaf size, leaf area (cm2), number of flower per plant, number of fruit per plant, fruit length (cm), fruit girth (cm), fruit weight (g) of strawberry was less vigorous near the Lohakat tree base. Highest number of flower per plant (52.87), fruit per plant (31.13) and percent fruit setting (58.88) were in open field condition which were almost identical in 1.0-1.5m distance area (51.83, 30.45 and 58.75%) and lowest value was recorded in0-0.5m distance area (26.08, 12.03 and 46.13%) from tree base. Maturity period of strawberry fruit decreased with decreasing distance from tree base and average maturity period was 18.0days and it ranges from 13-25 days. Individual fruit weight was highest in open field condition (17.81g) followed by 1.0-1.5m(17.53g), 0.5-1.0m (11.8g) and 0-0.5m (7.45g) distance area from Lohakat tree base. Yield of fruit was highest in open field condition 33.00t/ha which was 3.73, 56.35 and 83.84% lower in1.0-1.5m, 0.5-1.0m and 0-0.5m distance area from Lohakat tree base, respectively.

Rakib (2013) conducted an experiment to study the growth and yield of winter vegetables i.e. radish under different distance from Mango, Lemon and Guava tree, and he found that radish as vegetables and seed production was gradually increased with increasing distance from the tree base. Yield of radish as vegetables and seeds was highest in open field condition. However, radish as vegetables in association with mango reduced by 3.43%, 28.32%, and 49.85% and as seed yield reduced by 15.38%, 38.46% and 69.23% respectively in 3.0-4.5 feet, 1.5-3.0 feet and<1.5 feet distance from tree base. Radish as vegetables in association with guava tree reduced by10.84%, 39.26% and 58.94% and as seed reduced by 30.77%, 46.15% and 73.03% respectively in 3.0-4.5 feet, 1.5-3.0 feet and <1.5 feet distance from tree. Radish as vegetables in association with lemon tree reduced 22.5%, 50.68% and 74.20% and seed yield reduced by 46.15%,61.54% and 80.76% respectively in 3.0-4.5 feet, 1.5-3.0 feet and <1.5 feet distance from lemon tree base. Both as vegetable or seed production of radish in association of these three fruit trees are rank as Mango> Guava > Lemon. Growth of all fruit trees was observed as height and girth increment. Height and girth increment of Mango, Guava and Lemon tree was little bit higher under control (without radish) condition.

Uddin (2013) evaluates the growth performance of winter crops viz. carrot grown under Akashmoni tree saplings of different distances. The result showed that among the morphological characteristics of winter crops plant height, no. of leaves/plant, length and breadth of leaves, no. of branches/plant, weight of leaves/plant, weight of stem/plant, leaf stem ratio, increased consistently with the increase of distance from sapling. The growth characteristics of Eucalyptus were significantly influenced by the interaction of the crops.

Rahman (2013) conducted an experiment to study the growth and yield of three winter vegetables i.e. chilli, radish, and sweet gourd under different distance from Akashmoni tree, and he found that all the parameters i.e plant height, no. of leaves $plant^{-1}$, no. of branches $plant^{-1}$,leaf size, no. of fruits $plant^{-1}$, average no. of male and female flower $plant^{-1}$, length of fruits, girth of fruit, no. of fruits $plant^{-1}$, average weight of fruit, fresh yield, dry yield, yield were increased gradually with increasing distance from Akashmoni tree.

Hasan (2013) evaluates the growth performance of two winter crops viz. radish and bitter gourd grown under Eucalyptus tree saplings of different distances. The result showed that among the morphological characteristics of winter crops plant height, no. of leaves/plant, length and breadth of leaves, no. of branches/ plant, weight/plant, weight/fruit, fresh and dry yield, increased consistently with the increase of distance from sapling. The growth characteristics of Eucalyptus were significantly influenced by the interaction of the crops.

Farhana (2013) conducted an experiment to study the growth and yield of winter vegetables i.e. spinach under different distance from lohakat tree, and she found that the growth and yield of spinach in association with Lohakat tree. The result showed that morphological characteristics viz. plant height, no. of leaves per plant, leaf size, weight (fresh and dry) per plant of pinach was less vigorous near the Lohakat tree base. Yield as vegetable was highest in open field condition which was 13.13 t/ha which was 2.5, 15.18 and 24.98% lower in 1.0-1.5m, 0.5-1.0mand 0-0.5m distance area from Lohakat tree base, respectively. In every period of observation it was found that morphological parameters of spinach were remarkably less vigorous in close contact of Lohakat tree. Seed yield of spinach was also highest in open field condition which was 13.13 t/ha which was almost identical in the area 1.0-1.5m from tree base. Seed yield remarkably reduced in the near area of Lohakat tree and it was 37.06 and 69.30 % lower in 0.5-1.0m and 0-0.5m distance area from Lohakat tree base, respectively.

Effect of Shade on Plant Growth and Development

Alley cropping Agroforestry systems 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. Photo-synthetically active radiation 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).

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

Effect of Light on Plant Growth and Development

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).

Importance of Mahogany (*Swietenia mahagoni)* in Agroforestry System

This is an upright tree with a rounded, symmetrical crown of medium density. Mahogany can reach 75 feet in height with a 50-foot-spread but is more often seen at 40 to 50 feet tall and wide. After a period of winter rest, leaflets of the existing foliage turn brown and the leaves begin to abscise sometime in March to May. This is a brief process as the tree is semi-deciduous. Old leaves are shed suddenly and are quickly replaced by fresh new foliage just before or during the onset of new growth. The very new leaves of the new growth are at first reddish-purple but soon become light green.

Mahogany is a kind of three tropical hard wood species of the genus *Swietenia*, indigenous to the Americas, part of the pan tropical chinaberry family, Meliaceae (Samuel, 2012). The three species are:

- Honduran or big-leaf mahogany (*Swietenia macrophylla*), with a range from Mexico to southern Amazonia in Brazil, the most widespread species of mahogany and the only true mahogany species commercially grown today. Illegal logging of *S. macrophylla*, and its highly destructive environmental effects, led to the species' placement of Convention on International Trade in Endangered Species (CITES), the first time that a high-volume, high-value tree was listed.

- West Indian or Cuban mahogany (*Swietenia mahagoni*), native to southern Florida and the Caribbean, formerly dominant in the mahogany trade, but not in widespread commercial use since World War II.
- *Swietenia humilis*, a small and often twisted mahogany tree limited to seasonally dry forests in Pacific Central America that is of limited commercial utility. Some botanists believe that *S. humilis* is a mere variant of *S. macrophylla*.

Mahogany has a straight, fine, and even grain, and is relatively free of voids and pockets which were suitable for agrofortestry system.

Importance of Summer Vegetable Crops

Vegetables are usually recognized as cheap, easily available sources of carbohydrates, proteins, minerals and vitamins. Importance of four studied summer vegetables such as Kalmi, Red amaranth, Indian spinach and Stem Amaranth are as follows:

Importance of Kalmi

Kalmi or Gima kalmi (*Ipomoea reptans* poir) is a leafy vegetable grown in Bangladesh generally in summer season, belongs to the family Convolvulaceae. It is an important vegetable of the South East Asia, and is widely grown throughout the South East Asian countries, Australia and some parts of Africa (Hossain and Siddique, 1982). The crop is also known as kangkong, swamp cabbage, water convolvulus, water spinach etc. (Tindal, 1983). Gima kalmi was developed from an introduced strain of Kangkong brought from Taiwan by the Citrus and Vegetable Seed Research Centre of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur (Rashid *et al*., 1999).

In Bangladesh most of the vegetables are produced in summer and winter season, while in between these two seasons, there is a lag period when scarcity of vegetables occurs. Introduction of Gima kalmi is a positive achievement since it can be grown in summer and rainy season (Shinohara, 1980). Although similar, but aquatic type of local Kalmi is naturally grown in ponds or marshy land of Bangladesh, Gima kalmi has a special significance, because it grows in upland soil with an appreciable yield potential of foliage. Unlike the Bangladeshi local Kalmi, Gima kalmi grows erect producing heavy foliage.

Gima kalmi is a very important leafy vegetable from the nutritional point of view. 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). Since it requires low input, easy to grow, and is suitable for growing in summer, its cultivation should be increased. There are, however, signs of its gaining popularity among the Bangladeshi vegetable growers and consumers.

Importance of Red Amaranth

Cooked amaranth leaves are a good source of vitamin A, vitamin C, and folate; they are also a complementing source of other vitamins such as thiamine, niacin, and riboflavin, plus some dietary minerals including calcium, iron, potassium, zinc, copper, and manganese. Cooked amaranth grains are a complementing source of thiamine, niacin, riboflavin, and foliate, and dietary minerals including calcium, iron, magnesium, phosphorus, zinc, copper, and manganese - comparable to common grains such as wheat germ, oats and others.

Importance of Indian spinach

Indian spinach (*Basella alba* L.) commonly known as *poi* and belongs to the family Basellaceae.It is a popular summer leafy vegetable widely cultivated in Bangladesh, India, in Tropical Asia, Africa. It is very popular vegetable in Bangladesh and demand is increasing day by day. Indian spinach is a fleshy annual or biennial, twining much branched herb with alternate leaves. Leaves are broadly ovate and pointed at the apex. Flowers are white or pink, small sessile in cluster on elongated thickened peduncles in an open branched inflorescence. Fruit is enclosed in fleshy perianth.

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. All the cultivars are trained on poles, pandals or trellis or grown on ground (Bose and Som, 1990). The fresh tender leaves and stems are consumed as leafy vegetable after cooking. As half of the water soluble substance may be lost by boiling in water, it is preferable to cook the leaves in soups and stews. Indian spinach is popular for its delicate, crispy, texture and slightly sweetter taste as fresh condition.

Importance of 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. It is mainly grown during summer and rainy season in our country. The plant has fleshy stem and leaves (Bose and Som, 1986). This vegetable is important for its quick and vigorous growth habit and also for higher yield potentiality. More or less it is widely cultivated in Bangladesh, India, in tropical and subtropical parts of Asia, Africa and Central America (Hardwood, 1980).

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.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in central farm of Sher-e-Bangla Agricultural University during the period from April to July, 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 are given below:

Experimental site

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, 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).

Soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. The soil was having a texture of silty clay with pH and cation Exchange capacity 5.6 and 2.64 meq/100 g soil, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Appendix I (Khatun, 2014).

Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, 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 average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

Tree and plant materials

In this study,25 years old Mahogany tree were used as tree components. The leafy vegetable ie;Kalmi- *Ipomoea reptans* poir (Ghima Kalmi), Red Amaranth- *Amaranthus Gangeticus* Linn. (RM-2), Indian Spinach- *Basella alba* L. (Lal Puishak motadoga) and Stem Amaranth -*Amaranthus viridus* (Baromashi danta) were used as planting materials in this study. The seeds of these vegetables were collected from Siddique Bazar, Dhaka.

Treatments of the experiment

The experiment consists of two factors:

Factor A: Orientation of planting (2)

i) O_1: East facing

ii) O_2: West facing

Factor B: Distance of planting (5 levels)

i) D_0: Planting leafy vegetables at full sunlight

ii) D_1: Planting leafy vegetables at 3.5 m apart from mahogany trees

iii) D_2: Planting leafy vegetables at 4.0 m apart from mahogany trees

iv) D_3: Planting leafy vegetables at 4.5 m apart from mahogany trees

v) D_4: Planting leafy vegetables at 5.0 m apart from mahogany trees

There were in total 10 (2×5) treatment combinations such as O_1D_0, O_1D_1, O_1D_2, O_1D_3, O_1D_4, O_2D_0, O_2D_1, O_2D_2, O_2D_3 and O_2D_4.

Experimental design

Seeds of four leafy vegetable such as Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were sown with maintaining distinct orientations and distances following the Randomized Complete Block Design (RCBD) with three replications. Each treatment combination of orientation and distance of planting was replicated 3 times. Each vegetable will be considered as an individual experiment. The layout of the experiment is shown in Figure 1.

Land preparation

The experimental land was first opened on 24th March, 2014 and the operation was done by spade. Then the land was fallow for few days. All crop residues and weeds were removed from the field and finally the land was properly leveled.

Crop establishment and management

Seed sowing

Seeds four leafy vegetables such as Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were directly sown in the experimental plot on 3rd May, 2014 and spacing was 20 cm × 30 cm maintained.

Fertilizer application

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

For Kalmi

Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45DAS
Cow dung	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			

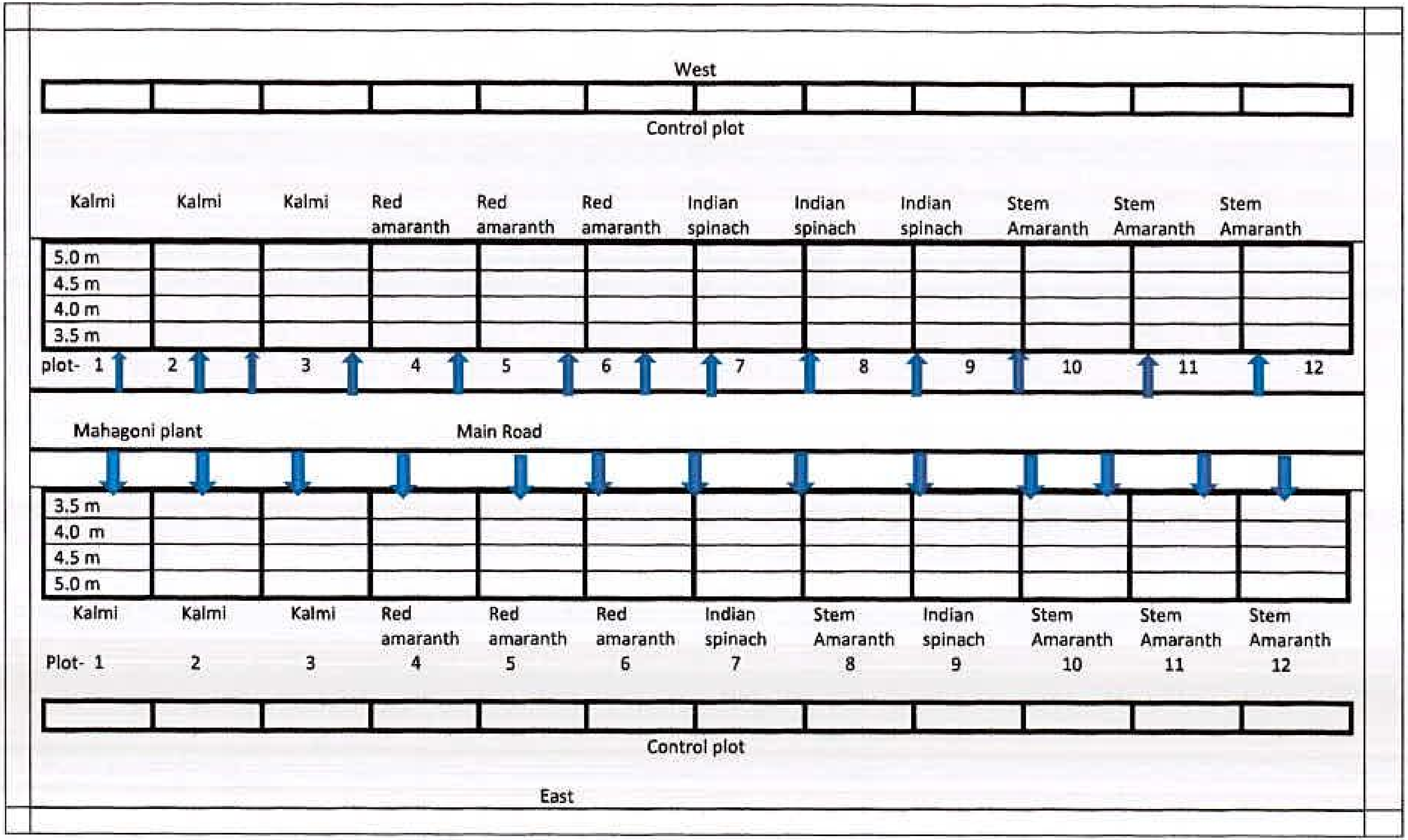

Figure-1. Layout of the experimental plot

For Indian spinach

Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45DAS
Cow dung	20 ton	100	--	--	--
Nitrogen as Urea	200 kg	--	33.33	33.3	3333
P_2O_5 (as TSP)	120 kg	100	--	--	--
K_2O (as MP)	180 kg	100	--	--	--

For Red Amaranth

Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45DAS
Cow dung	20 ton	100	--	--	--
Nitrogen as Urea	200 kg	--	33.33	33.3	3333
P_2O_5 (as TSP)	120 kg	100	--	--	--
K_2O (as MP)	200 kg	100	--	--	--

For Steam Amaranth

Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45DAS
Cow dung	20 ton	100	--	--	--
Nitrogen as Urea	200 kg	--	33.33	33.3	3333
P_2O_5 (as TSP)	100 kg	100	--	--	--
K_2O (as MP)	200 kg	100	--	--	--

Thinning and gap filling

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

Plant protection

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth borer (*Marucat estulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mg with 1 liter water for two times at 15 days interval after seedlings germination to control the insects.

Weeding and irrigation

To keep the plots free from weeds, weeding was done at 10 days interval for experimental plots and control plots. The plots were irrigated three times per month by pipe to supply sufficient soil moisture for the vegetable.

Harvesting

Kalmi and Indian spinach were harvested based on suitable size for consume; first harvesting was done at 30 days after sowing (DAS). Then 60 days after seed sowing, and 90 DAS at 3rd June, 2014, 3rd July, 2014 and 3rdAugust,2014. Red Amaranth was harvested at 30 DAS at 3rdJune. Stem Amaranth was harvested at 60 DAS in 3rd July.

Sampling procedure and data collection

The necessary procedures were followed to collect the data for growth, yield and yield attributes. Plant samples were collected randomly from all plot. Based on the nature of sample plants were collected on suitable size for consume. Five representative sample plants from each plot were randomly selected from each plot for data collection and following parameters were recorded. In case of several time of harvesting ,weight from individual harvested plot was recorded and finally yield was expressed in plant as well as plot and harvest.

In case of Indian Spinach and Kalmi

- Plant height at 30, 60 and 90 (DAS) after harvesting
- Number of leaves at 30, 60 and 90 (DAS) after harvesting
- Fresh weight at 30, 60 and 90 (DAS) after harvesting
- Dry weight at 30, 60 and 90 (DAS) after harvesting
- Yield /plot and yield/ha at 30, 60 and 90 (DAS) after harvesting

In case of Red Amaranth and steam Amaranth

- Plant height at harvesting time
- Number of leaves at harvesting time
- Fresh weight at harvesting time
- Dry weight at harvesting time
- Yield /plot and yield/ha at harvesting time

Light measurements

Light measured by Lux Meter on each vegetable crop rows as a function of distance from the tree base. It was done to determine the extent of shading by the tree species and expressed as lux .Light intensities were measured at 4 distance (D_1=3.5 m, D_2=4m, D_3=4.5m and D_4=5 m) from the tree base to vegetables lines. Light intensities were measured above the canopy of vegetable crops at1.00-10.00 am, 1.00-2.00 pm, 4.00-5.00pm using Lux meter at 3times per month and collected data were averaged and express as lux.

Soil moisture measurement

Soil moisture measured by Soil Moisture Meter on each vegetable crop rows as a function of distance from the tree base. It was expressed as percent (%) .Soil moisture were measured at 4 distance (D_1=3.5 m, D_2= 4m, D_3=4.5m and D_4= 5 m) from the tree base to vegetable lines. Soil moisture was measured 10 cm deep soil adjacent to main root of vegetable crops at 1.00-10.00 am, 1.00-2.00 pm, 4.00-5.00 pm in 3 times per month.

Soil temperature measurement

Soil temperature measured by Soil Temperature Meter on each vegetable crop rows as a function of distance from the tree base. It was express as degree centigrade (^{0}C).Soil temperature were measured at 4 distance (D_1=3.5 m, D_2= 4m, D3 =4.5m and D_4= 5 m) from the tree base to vegetables lines. Soil temperature was measured 10 cm deep soil adjacent to main root of vegetable crops at 1.00-10.00 am, 1.00-2.00 pm, 4.00-5.00 pm in 3 times per month.

Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference between orientation and distance from the tree base.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 5% level of probability (Gomez and Gomez, 1984).

Chapter IV
Results & Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to screening of some leafy vegetables under Mahogany tree based agroforestry system. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix III-XI. The results have been presented with the help of table and graphs and possible interpretations have been given under the following headings:

Plant height

Effect of orientation

Plant height of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (O). Statistically, the Tallest plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth (37.68, 66.61, 87.06 and 79.95 cm, respectively) were recorded, when these vegetables were grown in east side of Mahogany line (O_1- east facing). However, the shortest plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). The increased plant height may be due to decreased PAR. Shaded condition increased internode length and increased cell division. Leonardo (1996) found increased plant height, stomata density, transpiration rate and photosynthesis rate in peppers at low PAR condition.

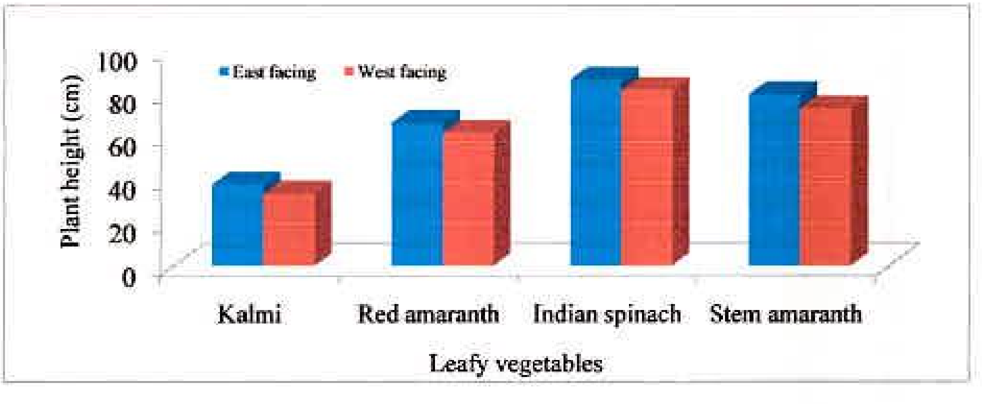

Figure 2. Effect of orientation of planting on plant height for Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system.

Effect of distance

Plant height of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Figure 3). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the tallest plant (38.90, 70.69, 95.54 and 85.81 cm, respectively) was observed from D_3 (distance 4.5), which was statistically similar (36.19, 66.38, 90.65 and 81.97 cm, respectively) with D_4 (distance 5.0 m). The statistically similar result (35.05, 64.93, 87.88 and 79.70 cm, respectively) was found when those vegetable grown in control condition D_0 (under full sunlight). However, the shortest plant (31.71, 57.08, 66.42 and 60.92 cm, respectively) was found from D_1 (distance 3.5 m) which was followed (35.97, 62.01, 82.10 and 75.29 cm, respectively) by D_2 (distance 4.0 m). Shade was comparatively higher beneath the tree and apart from the tree, it was reduced, correspondingly. Under tree, shade induced apical dominance and increased plant height, simultaneously. Anwar (2013) reported that plant height of bottle gourd was increased gradually with the increase of planting distance from the Akashmoni and Lambu tree. Ummah (2012), Habib *et al.,* (2012) reported the same result.

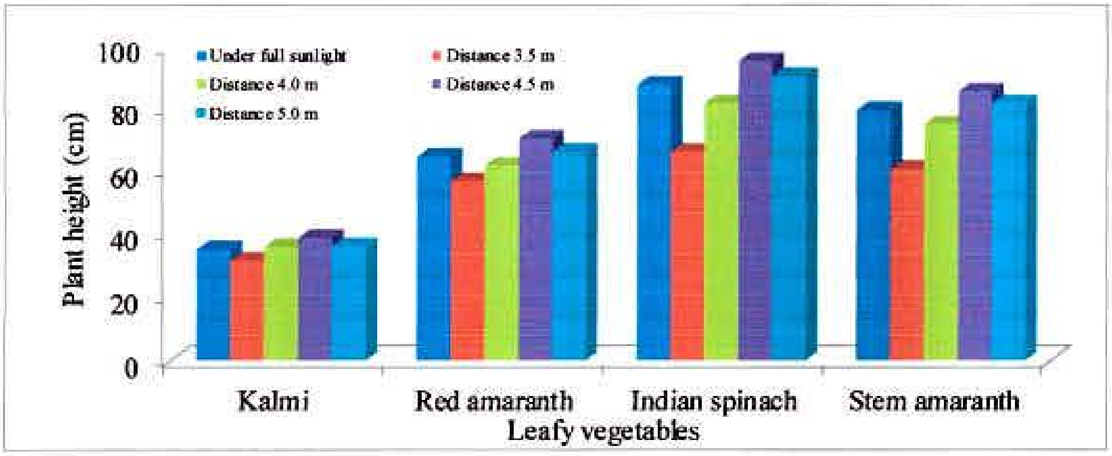

Figure 3. Effect of distance of planting on plant height for Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system.

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on plant height of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 1). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the tallest plant (41.86, 76.35, 98.58 and 87.09 cm, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the shortest plant (29.16, 53.16, 65.98 and 60.25 cm, respectively) were recorded from treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increases its apical part by cell division. That's why; crop under shade increased its height than crops under full sunlight.

Table 1. Interaction effect of orientation and distance of planting on plant height of Kalmi, Red amaranth, Indian spinach and Stem amaranth vegetables under Mahogany tree based agroforestry system

Treatments	Plant height (cm)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1D_0	34.92 cd	63.99 bc	84.70 b	79.99 a
O_1D_1	34.25 cd	60.99 bc	66.86 c	61.58 b
O_1D_2	40.67 ab	66.83 b	93.68 ab	86.37 a
O_1D_3	41.86 a	76.35 a	98.58 a	87.09 a
O_1D_4	36.67 bc	64.91 b	91.48 ab	84.74 a
O_2D_0	35.18 cd	65.86 b	91.06 ab	79.41 a
O_2D_1	29.16 e	53.16 d	65.98 c	60.25 b
O_2D_2	31.26 de	57.19 cd	70.53 c	64.21 b
O_2D_3	35.95 cd	65.03 b	92.50 ab	84.54 a
O_2D_4	35.71 cd	67.86 b	89.82 ab	79.19 a
CV (%)	7.03	6.17	6.99	8.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Number of leaves per plant

Effect of orientation

Number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Table 2). Statistically, the higher number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth (53.55, 66.29, 71.83 and 71.91, respectively) were recorded when these vegetables were grown in east side of Mahogany line (O_1- east facing). The lowest number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). The increased number of leaves may be due to decreased PAR (Photosynthetically Active Radiation) increased internode length and increased cell division.

Table 2. Effect of orientation of planting on number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth vegetables under Mahogany tree based agroforestry system

Treatments	Number of leaves per plant			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1	53.55 a	66.29 a	71.83 a	71.91a
O_2	50.00 b	62.56 b	67.04 b	65.37 b
CV(%)	6.20	5.16	3.52	5.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

Effect of distance

Number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Table 3). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest number of leaves per plant (57.73, 69.67, 76.37 and 76.67, respectively) were observed from D_3 (distance 4.5). However, the lowest number of leaves per plant (40.80, 57.07, 62.13 and 56.53, respectively) were found from D_1 (distance 3.5 m). Shade was comparatively higher beneath the tree and apart from the tree, it was reduced, correspondingly. Ummah (2012) reported that, the number of leaves was decreased gradually when distance reduced in association of Mahogany tree.

Table 3. Effect of distance of planting on number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth vegetables under Mahogany tree based agroforestry system

Treatments	Number of leaves per plant			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
D_0	53.87 ab	66.00 a	71.73 b	72.40 a
D_1	40.80 c	57.07 c	62.13 d	56.53 c
D_2	51.40 b	61.93 b	65.13 c	63.93 b
D_3	57.73 a	69.67 a	76.37 a	76.67 a
D_4	55.07 ab	67.47 a	71.80 b	73.67 a
CV(%)	6.20	5.16	3.52	5.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_0: Planting leafy vegetables under full sunlight;

D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;

D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 4). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest number of leaves per plant (59.73, 71.73, 79.20 and 83.93, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest number of leaves per plant (40.67, 55.60, 60.13 and 55.00, respectively) were recorded from treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increases its apical part by cell division. That's why; crop under shade increased its number of leaves per plant than crops under full sunlight.

Table 4. Interaction effect of orientation and distance of planting on number of leaves per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Number of leaves per plant			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
O_1D_0	51.33 b	64.93 b	73.93 b	75.40 bc
O_1D_1	40.94 c	58.53 c	64.13 d	58.07 fg
O_1D_2	59.33 a	67.60 ab	69.00 c	65.27 de
O_1D_3	59.73 a	71.73 a	79.20 a	83.93 a
O_1D_4	56.40 ab	68.67 ab	72.87 bc	76.87 b
O_2D_0	56.40 ab	67.07 ab	69.53 bc	69.40 cde
O_2D_1	40.67 c	55.60 c	60.13 d	55.00 g
O_2D_2	43.47 c	56.27 c	61.27 d	62.60 ef
O_2D_3	55.73 ab	67.60 ab	73.53 bc	69.40 cde
O_2D_4	53.73 ab	66.27 ab	70.73 bc	70.47 bcd
CV(%)	6.20	5.16	3.52	5.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Fresh weight per plant

Effect of orientation

Fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Table 5). Statistically the higher fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth (65.58, 88.47, 90.93 and 84.09 g, respectively) were recorded when these vegetables were grown in east side of Mahogany line (O_1- east facing). The lower fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). The increased fresh weight per plant may be due to decreased light intensity increased internode length and increased cell division.

Table 5. Effect of orientation of planting on fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Fresh weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1	65.58 a	88.47 a	90.93 a	84.09 a
O_2	62.32 b	83.26 b	87.27 b	80.23 b
CV(%)	4.86	4.93	4.41	4.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

Effect of distance

Fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Table 6). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest fresh weight per plant (70.08, 94.01, 95.62 and 88.68 g, respectively) were observed from D_3 (distance 4.5), which was statistically similar (68.99, 91.67, 92.13 and 85.24 g, respectively) with D_4 (distance 5.0 m). The statistically similar result (67.76, 88.68, 91.80 and 84.82 g, respectively) was found when those vegetable grown in control condition D_0 (under full sunlight). However, the lowest fresh weight per plant (52.86, 72.48, 79.86 and 72.83 g, respectively) were found from D_1 (distance 3.5 m) which was followed (60.06, 82.49, 86.08 and 79.23 g, respectively) by D_2 (distance 4.0 m). Shade was comparatively higher beneath the tree and apart from the tree, it was reduced, correspondingly. Under tree, shade induced apical dominance and increased fresh weight per plant, simultaneously. Islam *et al*., (2009) reported that fresh weight decreased consistently with the decrease of distance from the tree.

Table 6. Effect of distance of planting on fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany trees based agroforestry system

Treatments	Fresh weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
D_0	67.76 a	88.68 a	91.80 a	84.82 a
D_1	52.86 c	72.48 c	79.86 c	72.83 c
D_2	60.06 b	82.49 b	86.08 b	79.23 b
D_3	70.08 a	94.01 a	95.62 a	88.68 a
D_4	68.99 a	91.67 a	92.13 a	85.24 a
CV(%)	4.86	4.93	4.41	4.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_0: Planting leafy vegetables under full sunlight;
D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees
D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;
D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees
D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 7). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest fresh weight per plant (75.63, 97.81, 98.91 and 92.04 g, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest fresh weight per plant (52.37, 68.65, 79.05 and 71.33 g, respectively) were recorded from treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increases its apical part by cell division and ultimately the highest fresh weight per plant. That's why; crop under shade increased its plant height, number of leaves per plant and ultimately the highest fresh weight per plant than crops under full sunlight.

Table 7. Interaction effect of orientation and distance of planting on fresh weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Fresh weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1D_0	66.39 b	88.91 b	89.38 b	82.52 b
O_1D_1	53.35 c	76.31 c	80.68 c	73.85 c
O_1D_2	63.34 b	88.54 b	91.98 ab	85.12 ab
O_1D_3	75.63 a	97.81 a	98.91 a	92.04 a
O_1D_4	69.18 b	90.75 ab	93.70 ab	86.91 ab
O_2D_0	69.13 b	88.44 b	94.22 ab	87.11 ab
O_2D_1	52.37 c	68.65 d	79.05 c	71.82 c
O_2D_2	56.78 c	76.43 c	80.18 c	73.33 c
O_2D_3	64.53 b	90.21 ab	92.33 ab	85.33 ab
O_2D_4	68.80 b	92.59 ab	90.55 b	83.56 b
CV(%)	4.86	4.93	4.41	4.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting;
O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight;
D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;
D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Dry weight per plant

Effect of orientation

Dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Table 8). Statistically, the highest dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth (8.25, 8.29, 8.06 and 7.96 g, respectively) was recorded when these vegetables were grown in the east side of Mahogany line (O_1- east facing). The lowest dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). The increased dry weight may be due to increase, fresh weight per plant which may be due to decreased light intensity, increased internode length and increased cell division.

Table 8. Effect of orientation of planting on dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth vegetables under Mahogany tree based agroforestry system

Treatments	Dry weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1	8.25 a	8.29 a	8.06 a	7.96 a
O_2	7.58 b	7.71 b	7.46 b	7.56 b
CV(%)	3.93	4.56	5.43	4.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

Effect of distance

Dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany trees based agroforestry system (Table 9). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest dry weight per plant (8.38, 8.39, 8.65 and 8.40, respectively) were observed from D_3 (distance 4.5). However, the lowest dry weight per plant (7.09, 7.30, 6.67 and 6.33 g, respectively) were found from D_1 (distance 3.5 m). Shade was comparatively higher beneath the tree and apart from the tree, it was reduced, correspondingly. Under tree, shade induced apical dominance and increased fresh weight per plant, simultaneously which also leads to increased dry weight. Islam *et al*., (2009) reported that dry weight decreased consistently with the decrease of distance from the tree.

Table 9. Effect of distance of planting on dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Dry weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
D_0	8.16 a	8.22 a	8.06 b	8.20 a
D_1	7.09 c	7.30 c	6.67 d	6.33 c
D_2	7.67 b	7.76 b	7.24 c	7.57 b
D_3	8.38 a	8.39 a	8.65 a	8.40 a
D_4	8.29 a	8.30 a	8.17 ab	8.32 a
CV(%)	3.93	4.56	5.43	4.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 10). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest dry weight per plant (8.88, 8.88, 9.25 and 9.03 g, respectively) were observed from the treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest dry weight per plant (6.87, 7.01, 6.32 and 6.30 g, respectively) were recorded from treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increases its apical part by cell division and the ultimately the highest fresh weight per plant and as well as the highest dry weight per plant.

Table 10. Interaction effect of orientation and distance of planting on dry weight per plant of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment	Dry weight per plant (g)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1D_0	8.24 bc	8.12 bc	8.00 bc	7.94 bc
O_1D_1	7.31 d	7.60 cd	7.03 de	6.36 d
O_1D_2	8.32 abc	8.34 ab	6.98 de	7.76 c
O_1D_3	8.88 a	8.88 a	9.25 a	9.03 a
O_1D_4	8.51 ab	8.49 ab	9.03 a	8.72 a
O_2D_0	8.09 bc	8.33 ab	8.11 b	8.46 ab
O_2D_1	6.87 d	7.01 d	6.32 e	6.30 d
O_2D_2	7.02 d	7.18 d	7.50 bcd	7.37 c
O_2D_3	7.87 c	7.90 bc	8.05 bc	7.78 c
O_2D_4	8.07 bc	8.11 bc	7.31 cd	7.92 bc
CV(%)	3.93	4.56	5.43	4.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Yield per plot

Effect of orientation

Yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Table 11). Statistically ,the higher yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth (6.44, 7.08, 8.87 and 6.63 kg, respectively) were recorded when these vegetables were grown in the eastern side of Mahogany line (O_1- east facing). The lower yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). Ding and Su (2010) reported that tree shading reduced the crop yield by 27 and 22% in western and eastern regions, respectively, and also, the mean crop yield for western side was 23% lower than the eastern side.

Table 11. Effect of orientation of planting on yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment	Yield per plot (kg)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1	6.44 a	7.08 a	8.87 a	6.63 a
O_2	6.11 b	6.55 b	8.36 b	6.18 b
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting, O_2: West facing planting

Effect of distance

Yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Table 12). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest yield per plot (7.14, 7.84, 9.64 and 7.72 kg, respectively) were observed from D_3 (distance 4.5), which was statistically similar (6.91, 7.56, 9.48 and 7.13 kg, respectively) with D_4 (distance 5.0 m). However, the lowest yield per plot (4.58, 4.98, 6.73 and 4.36 kg, respectively) were found from D_1 (distance 3.5 m) which was followed (6.21, 6.50, 7.89 and 6.12 kg, respectively) by D_2 (distance 4.0 m). Shade was comparatively higher beneath the tree and apart from the tree, it was reduced, correspondingly. Under tree, shade induced apical dominance and increased fresh weight per plant, simultaneously. Bali (2012) reported that yield of Okra was increased gradually with increasing distance from Lemon and Guava tree. Ummah (2012) and Anwar (2013) reported the same result.

Table 12. Effect of distance of planting on yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment	Yield per plot (kg)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
D_0	6.54 bc	7.21 ab	9.33 a	6.69 bc
D_1	4.58 d	4.98 c	6.73 c	4.36 d
D_2	6.21 c	6.50 b	7.89 b	6.12 c
D_3	7.14 a	7.84 a	9.64 a	7.72 a
D_4	6.91 ab	7.56 a	9.48 a	7.13 ab
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_0: Planting leafy vegetables under full sunlight;
D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees
D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;
D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees
D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 13). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest dry weight per plant (7.42, 8.07, 9.99 and 7.96 kg, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest yield per plot (4.63, 4.78, 6.66 and 4.18 kg, respectively) were recorded from treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increased its apical part by cell division and the ultimately the highest fresh weight per plant and as well as highest yield per plot. That's why; crop under shade increased its the highest yield per plot than crops under full sunlight.

Table 13. Interaction effect of orientation and distance of planting on yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Yield per plot (kg)			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
O_1D_0	6.37 b	7.02 a	9.38 ab	5.93 b
O_1D_1	4.52 d	5.17 b	6.79 c	4.53 c
O_1D_2	6.94 ab	7.59 a	8.57 b	7.61 a
O_1D_3	7.42 a	8.07 a	9.99 a	7.96 a
O_1D_4	6.92 ab	7.57 a	9.60 ab	7.10 a
O_2D_0	6.71 ab	7.41 a	9.28 ab	7.44 a
O_2D_1	4.63 d	4.78 b	6.66 c	4.18 c
O_2D_2	5.48 c	5.41 b	7.21 c	4.63 c
O_2D_3	6.86 ab	7.61 a	9.28 ab	7.48 a
O_2D_4	6.89 ab	7.56 a	9.35 ab	7.15 a
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting;

O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight;

D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;

D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Yield per hectare

Effect of orientation

Yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Table 14). Statistically, the higher yield per plot of Kalmi, Red amaranth, Indian spinach and Stem amaranth (35.75, 39.35, 49.27 and 36.83 ton, respectively) were recorded when these vegetables were grown in east side of Mahogany line (O_1-east facing). The lower yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing). 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.

Table 14. Effect of orientation and distance of planting on yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Yield per hectare (ton)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1	35.75 a	39.35 a	49.27 a	36.83 a
O_2	33.97 b	36.40 b	46.42 b	34.31 b
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

Effect of distance

Yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Table 15). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest yield per hectare (39.67, 43.55, 53.53 and 42.90 ton, respectively) were observed from D_3 (distance 4.5), which was statistically similar (38.37, 42.01, 52.65 and 39.59 ton, respectively) with D_4 (distance 5.0 m). However, the lowest yield per hectare (25.42, 27.65, 37.37 and 24.19 ton, respectively) were found from D_1 (distance 3.5 m). Under tree, shade induced apical dominance and increased yield, simultaneously. Singh *et al.* (1989) found that growth and yield of crops declined from 15% to 30% than that of sole crops as the distance from the tree rows decreased from 5 m to 0.3 m. Habib *et al.* (2012) reported that that the yield of the summer vegetables increased gradually with the increase of planting distance of the tree. Ahmed (2012) reported that the vegetables yield had reduced remarkably at 5 feet distant from tree base.

Table 15. Effect of distance of planting on yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment	Yield per hectare (ton)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
D_0	36.32 bc	40.08 ab	51.84 a	37.14 bc
D_1	25.42 d	27.65 c	37.37 c	24.19 d
D_2	34.51 c	36.10 b	43.82 b	34.02 c
D_3	39.67 a	43.55 a	53.53 a	42.90 a
D_4	38.37 ab	42.01 a	52.65 a	39.59 ab
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

D_0: Planting leafy vegetables under full sunlight;
D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees
D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees;
D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees
D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 16). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest yield per hectare (41.22, 44.82, 55.53 and 44.25 ton, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest yield per hectare (25.13, 26.56, 37.01 and 23.22 ton, respectively) were recorded from the treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line). Crops grown under shade tree intended to harvest more light for photosynthesis and increases its apical part by cell division and the ultimately the highest yield. That's why; crop under shade increased it's the highest yield than crops under full sunlight.

Table 16. Interaction effect of orientation and distance of planting on yield per hectare of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment	Yield per hectare (ton)			
	Kalmi	Red amaranth	Indian spinach	Stem amaranth
O_1D_0	35.39 b	38.99 a	52.14 ab	32.96 b
O_1D_1	25.72 d	28.73 b	37.73 c	25.17 c
O_1D_2	38.56 ab	42.16 a	47.59 b	42.29 a
O_1D_3	41.22 a	44.82 a	55.53 a	44.25 a
O_1D_4	38.44 ab	42.04 a	53.36 ab	39.46 a
O_2D_0	37.26 ab	41.17 a	51.53 ab	41.32 a
O_2D_1	25.13 d	26.56 b	37.01c	23.22 c
O_2D_2	30.45 c	30.04 b	40.06 c	25.75 c
O_2D_3	38.12 ab	42.27 a	51.54 ab	41.56 a
O_2D_4	38.30 ab	41.97 a	51.94 ab	39.72 a
CV(%)	6.17	8.68	6.91	8.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Light intensity

Effect of orientation

Light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Figure 4). Statistically, the higher light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth (13.67, 14.93, 13.89 and 14.57 lux, respectively) were recorded when these vegetables were grown in east side of Mahogany line (O_1- east facing). The lower light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing).

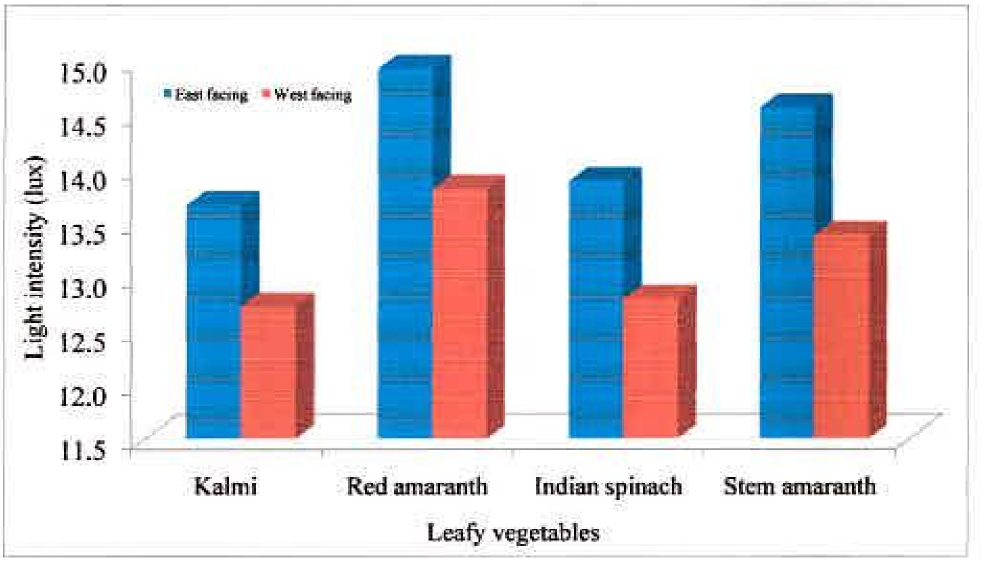

Figure 4. Effect of orientation of planting on light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system.

Effect of distance

Light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Figure 5). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest light intensity (15.08, 15.50, 15.14 and 15.43 lux, respectively) were observed from D_0 (Under full sunlight). However, the lowest light intensity (10.75, 12.78, 11.65 and 12.61 lux, respectively) were found from D_1 (distance 3.5 m).

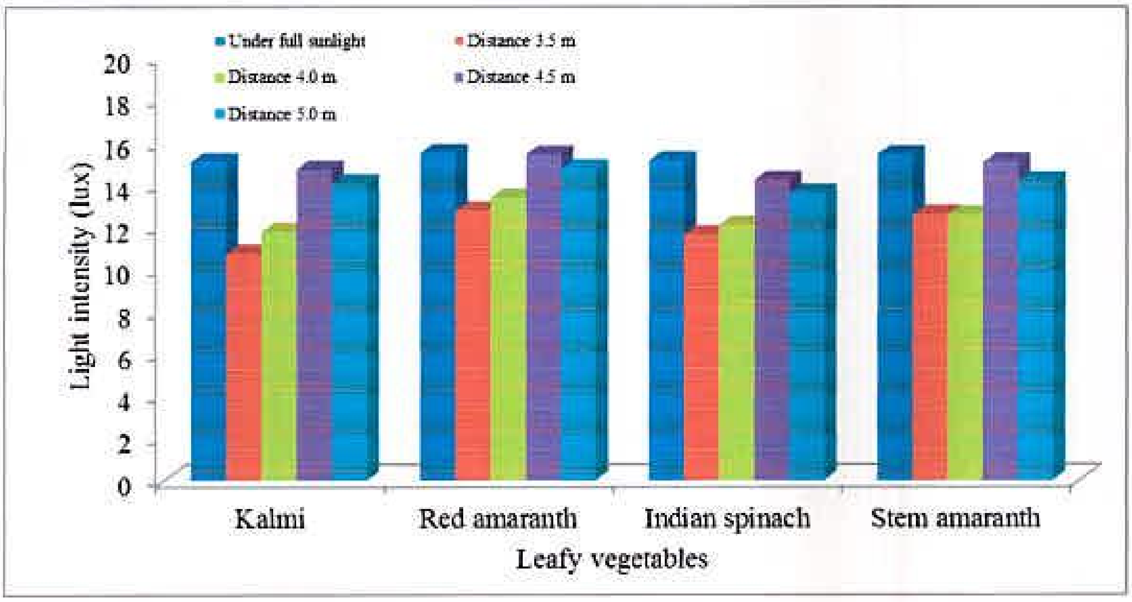

Figure 5. Effect of distance of planting on light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system.

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 17). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest light intensity (16.12, 16.33, 15.73 and 15.80 lux, respectively) were observed from treatment combination of O_2D_0 (West facing and full sunlight) and the lowest light intensity (9.50, 11.76, 10.86 and 10.91 lux, respectively) were recorded from treatment combination of O_2D_2 (West facing and 4m apart from Mahogany line).

Table 17. Interaction effect of orientation and distance of planting on light intensity of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatment Combinations	Light intensity (Lux)			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
O_1D_0	14.04 bc	15.09 bc	14.56 bc	15.07 abc
O_1D_1	11.07 d	13.13 d	12.37 e	13.10 e
O_1D_2	14.08 bc	15.02 bc	13.31 d	14.26 cd
O_1D_3	15.29 ab	15.92 ab	15.33 ab	15.28 ab
O_1D_4	13.86 c	15.11 bc	13.87 cd	14.38 bcd
O_2D_0	16.12 a	16.33 a	15.73 a	15.80 a
O_2D_1	10.44 de	12.43 de	10.92 f	12.12 f
O_2D_2	9.50 e	11.76 e	10.86 f	10.91 g
O_2D_3	14.17 bc	14.54 c	13.11 de	14.84 abcd
O_2D_4	13.43 c	14.46 c	13.37 d	14.00 de
CV(%)	5.57	4.52	3.70	5.79

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Soil moisture

Effect of orientation

Soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Figure 6). Statistically the higher soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth (54.01%, 53.34%, 52.55% and 51.43%, respectively) were recorded when these vegetables were grown in east side of Mahogany line (O_1- east facing). The lower soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from west side of Mahogany line (O_2- west facing).

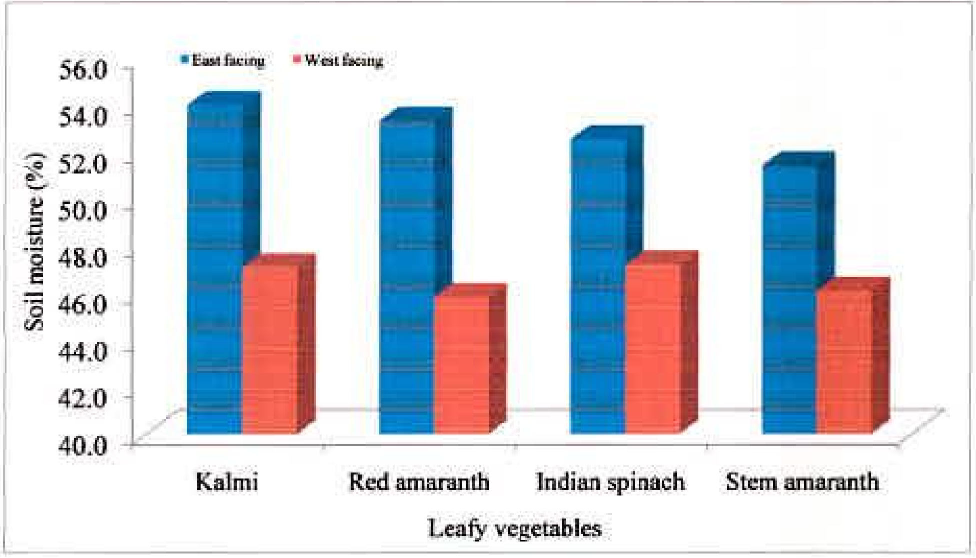

Figure 6. Effect of orientation of planting on soil moisture of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth under Mahogany trees based agroforestry system.

Effect of distance

Soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Figure 7). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest soil moisture (59.78%, 60.11%, 58.35% and 54.82%, respectively) were observed from D_3 (distance 4.5). However, the lowest soil moisture (37.63%, 36.35%, 38.32% and 42.27%, respectively) were found from D_1 (distance 3.5 m). Arya *et al.,* (2011) suggested that soil moisture were higher when grown under conjugation as compared to their sole cropping.

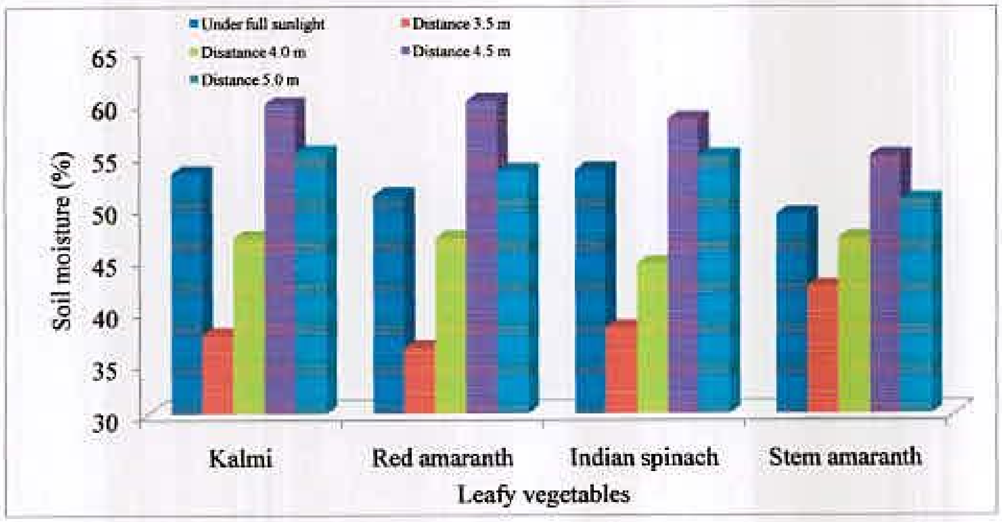

Figure 7. Effect of distance of planting on soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany trees based agroforestry system.

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 18). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest soil moisture (68.96%, 64.12%, 65.61% and 59.71%, respectively) were observed from treatment combination of O_1D_3 (East facing and 4.5 m apart from Mahogany line) and the lowest soil moisture (33.50%, 34.31%, 36.34% and 39.45%, respectively) were recorded from the treatment combination of O_2D_1 (West facing and 3.5 m apart from Mahogany line).

Table 18. Interaction effect of orientation and distance of planting on soil moisture of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany trees based agroforestry system

Treatments	Soil moisture (%)			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
O_1D_0	50.74 b	49.52 b	50.80 c	48.88 cde
O_1D_1	41.76 c	38.40 c	40.30 d	45.09 de
O_1D_2	51.85 b	57.55 ab	49.92 c	49.36 cd
O_1D_3	68.96 a	64.12 a	65.61 a	59.71 a
O_1D_4	56.76 b	57.10 ab	56.13 b	54.09 b
O_2D_0	55.67 b	52.66 b	56.22 b	49.55 cd
O_2D_1	33.50 d	34.31 c	36.34 d	39.45 f
O_2D_2	42.15 c	36.40 c	39.00 d	44.50 e
O_2D_3	50.61 b	56.10 ab	51.10 bc	49.92 bc
O_2D_4	53.67 b	49.71 b	53.49 bc	47.13 cde
CV(%)	7.80	11.24	5.53	5.00

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing planting; O_2: West facing planting

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 3.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 4.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 4.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 5.0 m apart from Mahogany trees;

Soil temperature

Effect of orientation

Soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of orientation (Figure 8). Statistically the higher soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth (31.13, 31.60, 33.43 and 33.00 ^{0}C, respectively) were recorded when these vegetables were grown in west side of Mahogany line (O_2- west facing). The lower soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded from east side of Mahogany line (O_1- east facing).

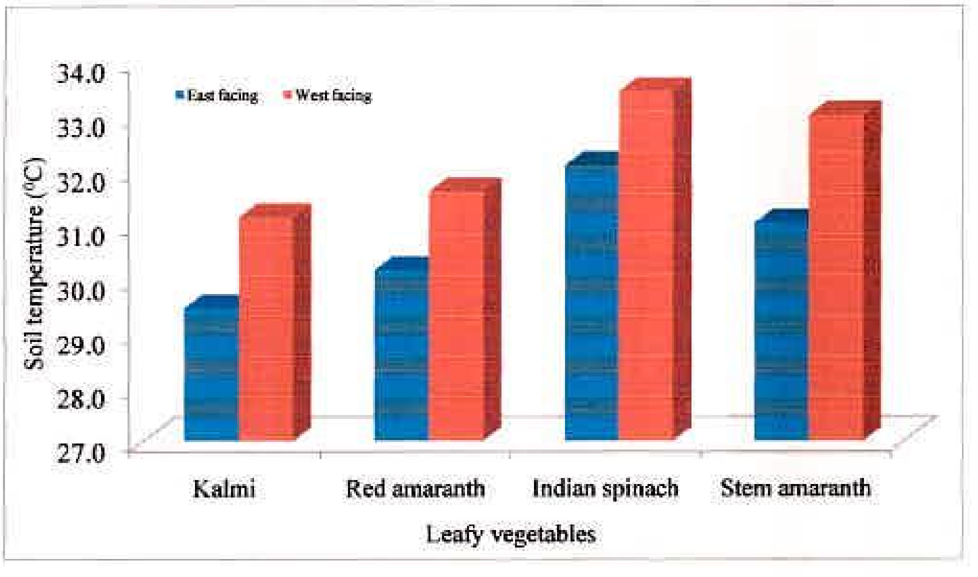

Figure 8. Effect of orientation of planting on soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany trees based agroforestry system.

Effect of distance

Soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth were recorded and found significant differences due to the effect of distance (D) under Mahogany tree based agroforestry system (Figure 9). In case of Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest soil temperature (33.12, 32.91, 35.07 and 34.41 ^{0}C, respectively) were obtained from D_3, which was statistically similar (31.93, 31.71, 33.80 and 33.06 ^{0}C, respectively) with D_4 and (31.13, 31.53, 33.56 and 32.99 ^{0}C, respectively) D_0. On the other hand, the lowest (26.86, 28.83, 29.82 and 29.09 ^{0}C, respectively) were found from D_1 which was followed by D_2 (28.43, 29.42, 31.50 and 30.51 ^{0}C, respectively).

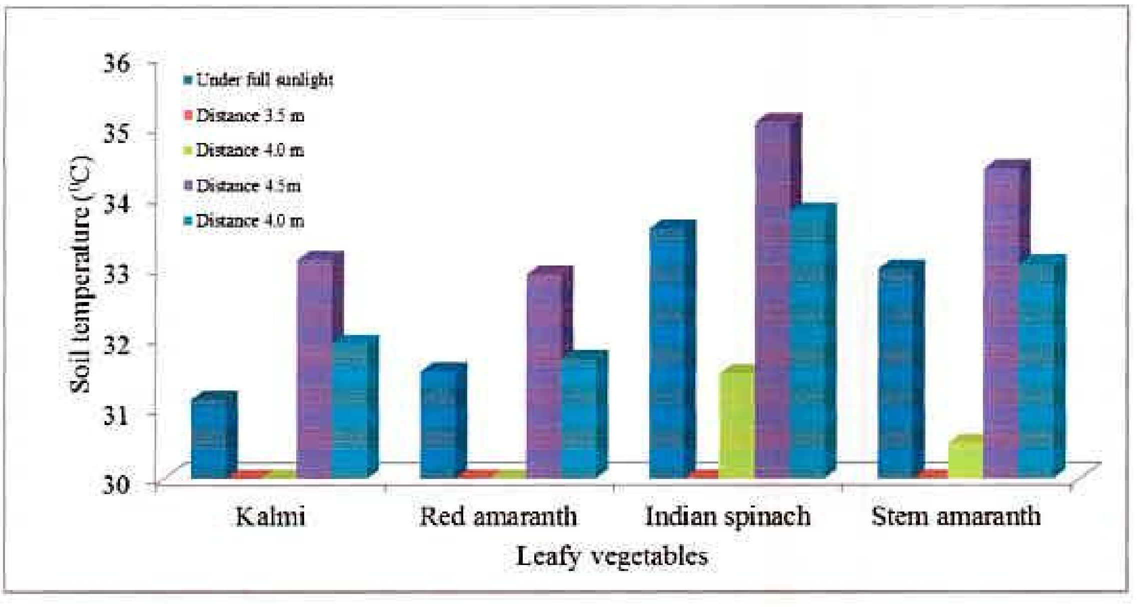

Figure 9. Effect of distance of planting on soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system.

Interaction effect

Interaction effect of different orientation and distance of planting showed significant variation on soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system (Table 19). For Kalmi, Red amaranth, Indian spinach and Stem amaranth, the highest soil temperature (34.84, 34.26, 36.29 and 36.09 ^{0}C, respectively) were observed from treatment combination of O_2D_3 (West facing and 4.5 m apart from Mahogany line) and the lowest soil temperature (25.46, 27.36, 29.23 and 26.23 ^{0}C, respectively) were recorded from treatment combination of O_1D_2 (East facing and 4 m apart from Mahogany line).

Table 19. Interaction effect of orientation and distance of planting on soil temperature of Kalmi, Red amaranth, Indian spinach and Stem amaranth under Mahogany tree based agroforestry system

Treatments	Soil temperature (^{0}C)			
	Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
O_1D_0	32.04 ab	32.40 ab	34.45 ab	33.87 ab
O_1D_1	26.67 d	28.48 de	29.56 d	29.34 bcd
O_1D_2	25.46 d	27.36 e	29.23 d	26.23 d
O_1D_3	31.41 ab	31.56 bc	33.86 ab	32.72 abc
O_1D_4	31.72 ab	31.01 bc	33.26 ab	32.92 abc
O_2D_0	30.22 bc	30.67 bcd	32.68 bc	32.11 abc
O_2D_1	27.04 cd	29.19 cde	30.08 cd	28.83 cd
O_2D_2	31.40 ab	31.49 bc	33.76 ab	34.80 a
O_2D_3	34.84 a	34.26 a	36.29 a	36.09 a
O_2D_4	32.13 ab	32.41 ab	34.34 ab	33.19 abc
CV(%)	6.12	4.31	4.93	7.63

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

O_1: East facing; O_2: West facing

D_0: Planting leafy vegetables under full sunlight; D_1: Planting leafy vegetables 0.5 m apart from Mahogany trees

D_2: Planting leafy vegetables 1.0 m apart from Mahogany trees; D_3: Planting leafy vegetables 1.5 m apart from Mahogany trees

D_4: Planting leafy vegetables 2.0 m apart from Mahogany trees;

Chapter V

Summary, Conclusion & Recommendation

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

The experiment was conducted at Central Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh for screening some of leafy vegetables in Mahogany tree based agroforestry system during the period from April to July, 2014. In this study the 25 years old previously established Mahogany tree were used as upper storied tree components. The lower stored tested vegetables were Kalmi, Red amaranth, Indian spinach and Stem amaranth. The experiment consists of two factors: Factor A: Orientation of planting (2) - O_1: East facing, O_2: West facing; Factor B: Distance of planting (5 levels) - D_0: Planting leafy vegetables under full sunlight, D_1: Planting leafy vegetables at 3.5 m apart from Mahogany trees, D_2: Planting leafy vegetables at 4.0 m apart from Mahogany trees, D_3: Planting leafy vegetables at 4.5 m apart from Mahogany trees and D_4: Planting leafy vegetables at 5.0 m apart from Mahogany trees. Four vegetables such as Kalmi, Red Amaranth, Indian spinach and Stem amaranth were sown as four individual experiment satisfying orientations and distances following the Randomized Complete Block Design (RCBD) with three replications.

Due to orientation Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth responded differently and the tallest plant (37.68, 66.61, 87.06 and 79.95 cm, respectively) was recorded from O_1, which the shortest plant (33.45, 61.82, 81.98 and 73.52 cm, respectively) from O_2. The maximum number of leaves per plant (53.55, 66.29, 71.83 and 71.91, respectively) was found from O_1, while the minimum number (50.00, 62.56, 67.04 and 65.37, respectively) from O_2. The highest fresh weight per plant (65.58, 88.47, 90.93 and 84.09 g, respectively) was recorded from O_1, whereas the lowest weight (62.32, 83.26, 87.27 and 80.23 g, respectively) from O_2. The highest dry weight per plant (8.25, 8.29, 8.06 and 7.96 g, respectively) was found from O_1, whereas the lowest weight (7.58, 7.71, 7.46 and 7.56 g, respectively) from O_2. The highest yield per plot (6.44, 7.08, 8.87 and 6.63 kg, respectively) was recorded from O_1, while the lowest yield (6.11, 6.55, 8.36 and 6.18 kg, respectively) from O_2. The highest yield per hectare (35.75, 39.35, 49.27 and 36.83 ton, respectively) was observed from O_1, and the lowest yield (33.97, 36.40, 46.42 and 34.31 ton, respectively) from O_2. The highest light intensity (13.67, 14.93, 13.89 and 14.57 lux, respectively) was found from O_1, whereas the lowest (12.73, 13.82, 12.80 and 13.39 lux, respectively) from O_2. The soil moisture (54.01%, 53.34%, 52.55% and 51.43%, respectively) was observed from O_1, whereas the lowest (47.12%, 45.84%, 47.23% and 46.11%, respectively) from O_2. The soil temperature (31.13, 31.60, 33.43 and 33.00 ^{0}C, respectively) from O_2, whereas the lowest (29.46, 30.16, 32.07 and 31.02 ^{0}C, respectively) from O_1.

When distance were taken into consideration, the performance of Kalmi, Red Amaranth, Indian spinach and Stem amaranth were found various significant effect the tallest plant (38.90, 70.69, 95.54 and 85.81 cm, respectively) was observed from D_3, while the shortest plant (31.71, 57.08, 66.42 and 60.92 cm, respectively) was found from D_1. The maximum number of leaves per plant (57.73, 69.67, 76.37 and 76.67, respectively) was recorded from D_3, again the minimum number (40.80, 57.07, 62.13 and 56.53, respectively) was obtained from D_1. The highest fresh weight per plant (70.08, 94.01, 95.62 and 88.68 g, respectively) was found from D_3 and, the lowest weight (52.86, 72.48, 79.86 and 72.83 g, respectively) was recorded from D_1. The highest dry weight per plant (8.38, 8.39, 8.65 and 8.40, respectively) was observed from D_3, while the lowest weight (7.09, 7.30, 6.67 and 6.33 g, respectively) was found from D_1. The highest yield per plot (7.14, 7.84, 9.64 and 7.72 g, respectively) was found from D_3, whereas the lowest yield (4.58, 4.98, 6.73 and 4.36 g, respectively) was found from D_1. The highest yield per hectare (39.67, 43.55, 53.53 and 42.90 ton, respectively) was observed from D_3, while the lowest yield (25.42, 27.65, 37.37 and 24.19 ton, respectively) from D_1. The highest light intensity (15.08, 15.50, 15.14 and 15.43 lux, respectively) was found from D_0, while the lowest (10.75, 12.78, 11.65 and 12.61 lux, respectively) was found from D_1. The highest soil moisture (54.01%, 53.34%, 52.55% and 51.43%, respectively) was obtained from

D_3, while the lowest (37.63%, 36.35%, 38.32% and 42.27%, respectively) was found from D_1. The highest soil temperature (33.12, 32.91, 35.07 and 34.41 ^0C, respectively) was obtained from D_3 and the lowest (26.86, 28.83, 29.82 and 29.09 ^0C, respectively) was found from D_1.

In consideration of the interaction effect (orientation and distance) for Kalmi, Red amaranth, Indian spinach and Stem amaranth, the tallest plant (41.86, 76.35, 98.58 and 87.09 cm, respectively) was observed from treatment combination of O_1D_3 and the shortest plant (29.16, 53.16, 65.98 and 60.25 cm, respectively) from O_2D_1. The maximum number of leaves per plant (59.73, 71.73, 79.20 and 83.93, respectively) was found from O_1D_3, while the minimum number (40.67, 55.60, 60.13 and 55.00, respectively) from O_2D_1. The highest fresh weight per plant (75.63, 97.81, 98.91 and 92.04 g, respectively) was obtained from O_1D_3, whereas the lowest weight (52.37, 68.65, 79.05 and 71.33 g, respectively) was found from O_2D_1. The highest dry weight per plant (8.88, 8.88, 9.25 and 9.03 g, respectively) was recorded from treatment combination of O_1D_3 and the lowest weight (6.87, 7.01, 6.32 and 6.30 g, respectively) was recorded from O_2D_1. The highest yield per plot (7.42, 8.07, 9.99 and 7.96 g, respectively) was obtained from treatment combination of O_1D_3, while the lowest yield (4.63, 4.78, 6.66 and 4.18 g, respectively) was found from O_2D_1. The highest yield per hectare (41.22, 44.82, 55.53 and 44.25 ton, respectively) was obtained from treatment combination of O_1D_3 and the lowest yield (25.13, 26.56, 37.01 and 23.22 ton, respectively) was found from O_2D_1. The highest light intensity (16.12, 16.33, 15.73 and 15.80 lux, respectively) was obtained from treatment combination of O_2D_0 and the lowest (9.50, 11.76, 10.86 and 10.91 lux, respectively) from O_2D_2. The highest soil moisture (68.96%, 64.12%, 65.61% and 59.71%, respectively) was observed from treatment combination of O_1D_3 and the lowest (33.50%, 34.31%, 36.34% and 39.45%, respectively) from of O_2D_1. The highest soil temperature (34.84, 34.26, 36.29 and 36.09 ^0C, respectively) was recorded from treatment combination of O_2D_3, while the lowest (25.46, 27.36, 29.23 and 26.23 ^0C, respectively) from O_1D_2.

Conclusion

Based on the findings of the study and keeping the objectives in mind, the following conclusion could be drowning.

1. Among the four leafy vegetables yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were better at east facing (O_1). Where light intensity and soil moisture were maximum. Soil temperature was minimum. On the other hand yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were the lower at west facing (O_2). Where light intensity and soil moisture were minimum. Soil temperature was maximum.

2. The yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were the best from 4.5 m apart from Mahogany trees (D_3). On the other hand yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were the lowest from 3.5 m apart from Mahogany trees (D_1).

3. The yield of Kalmi, Red Amaranth, Indian Spinach and Stem Amaranth were superior at east facing 4.5 m apart from Mahogany trees (O_1D_3). soil moisture was the highest. On an Average the lowest average yield of Kalmi, Red Amaranth, Indian Spinach and Stem were observed at west facing 3.5 m apart from Mahogany trees (O_2D_1). Where the lowest soil moisture was observed. And the soil temperature was comparatively higher.

4. Light intensity was the highest at treatment combination of O_2D_0, and the Lowest Light intensity was observed at treatment combination of O_2D_2.

A good soil Environment in terms of availability of soil moisture and soil temperature might favor the successful growth of four leafy vegetables. The finding of the present study reveals that planting vegetables under Mahogany tree at east facing-4.5m apart from Mahogany trees would be the best cropping pattern under the Mahogany (*Swietenia mahagoni*) based Agroforestry system.

Recommendation:

Based on the results and discussion of the study, the following recommendations are to be suggested:

1. Leafy vegetable condition under mahogany tree is economic with maintaining proper distance. Also east facing is suitable than west facing as it keep proper amount (%) of soil moisture ,soil temperature and light intensity.

2. Below ground competition for nutrient was not intensively studied in this experiment while the soil moisture and temperature were measured. Below ground competition should be studied for better explanations of findings.

3. Further study is needed to conduct in farmer's level at different ecosystems of Bangladesh.

4. More experiments may be carried out with other vegetables using different plant species at different distances.

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Appendices

APPENDICES

Appendix I. Characteristics of soil of experime ntal 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 April to July, 2014

Month (2014)	*Air temperature (°C)		*Relative humidity (%)	*Total rainfall (mm)
	Maximum	Minimum		
34.2	23.4	61	112	8.1
34.7	25.9	70	185	7.8
35.4	22.5	80	577	4.2
36.0	24.6	83	563	3.1

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Analysis of variance of the data on plant height of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	4.754	11.671	9.869	21.969
Orientation of planting (A)	1	133.685*	172.512*	193.451*	310.280*
Distance of planting (B)	4	161.101*	617.657 *	3021.895*	2225.252 *
Interaction (A×B)	4	91.818*	269.556*	628.016*	485.340 *
Error	18	112.421	282.181	731.630	719.584

* Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of leaves per plant of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Number of leaves per plant of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	3.685	7.243	7.795	3.624
Orientation of planting (A)	1	94.341*	104.533*	171.841*	320.133 *
Distance of planting (B)	4	256.927*	597.365*	784.453*	1635.338 *
Interaction (A×B)	4	89.121*	142.133*	125.899 *	136.907 *
Error	18	10.306	199.264	107.779	245.069

* Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on fresh weight per plant of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Fresh weight per plant (g) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	5.906	31.338	0.160	1.666
Orientation of planting (A)	1	79.590 *	203.008 *	100.613 *	111.516 *
Distance of planting (B)	4	1293.875 *	1791.630*	920.445 *	928.132 *
Interaction (A×B)	4	182.626 *	197.032 *	227.022 *	219.010*
Error	18	173.784	322.106	277.924	256.874

* Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on dry weight per plant of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Dry weight per plant (%) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	0.028	0.012	0.550	0.122
Orientation of planting (A)	1	3.367*	2.523 *	2.712 *	1.192 *
Distance of planting (B)	4	6. 936*	5.022 *	15.006*	18.034*
Interaction (A×B)	4	1.335 *	1.763 *	5.111*	2.771 *
Error	18	1.743	2.390	3.200	2.202

* Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on yield per plot of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square Yield per plot (kg) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	0.166	0.077	0.010	0.174
Orientation of planting (A)	1	0.771 *	2.112*	1.976*	1.535*
Distance of planting (B)	4	24.647*	31.469 *	38.347 *	39.702 *
Interaction (A×B)	4	3.081*	5.806*	11.692*	15.707*
Error	18	2.696	6.302	6.372	5.627

* Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield per hectare of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square Yield per hectare (ton) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	5.119	2.379	0.304	5.380
Orientation of planting (A)	1	23.789 *	65.197*	60.988 *	47.378 *
Distance of planting (B)	4	760.720*	971.264 *	1183.545 *	1225.369 *
Interaction (A×B)	4	95.083 *	179.199*	152.225 *	484.786*
Error	18	83.210	194.500	196.655	173.664

* Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on light intercity of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Light intensity (Lux) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	1.047	0.089	0.569	0.041
Orientation of planting (A)	1	34.167 *	9.291*	8.911*	10.384*
Distance of planting (B)	4	84.323 *	36.519*	51.235*	42.831*
Interaction (A×B)	4	6.504*	13.835 *	13.054 *	9.162 *
Error	18	9.747	7.608	4.390	5.042

* Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data on soil moisture of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Soil moisture (%) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	20.073	4.531	23.651	6.149
Orientation of planting (A)	1	356.663*	422.016 *	212.591 *	212.139*
Distance of planting (B)	4	1760.726*	1857.405 *	1633.227*	514. 472*
Interaction (A×B)	4	442.780*	467.152 *	360.403 *	88.216 *
Error	18	280.144	559.485	137.160	107.011

* Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data on soil temperature of Kalmi, Red amaranth, Indian Spinach and Stem Amaranth as influenced by orientation and distance of planting

Source of variation	Degrees of freedom	Mean square			
		Soil temperature (^0C) of			
		Kalmi	Red Amaranth	Indian Spinach	Stem Amaranth
Replication	2	0.044	0.298	1.370	0.988
Orientation of planting (A)	1	20.847*	15.588 *	13.867 *	29.601 *
Distance of planting (B)	4	159.916*	69.355 *	103.871*	111.544 *
Interaction (A×B)	4	55.241*	29.116 *	47.019 *	102.927*
Error	18	61.884	31.856	32.590	107.477

* Significant at 0.05 level of probability