VARIETAL PERFORMANCE OF POTATO UNDER LITCHI BASED AGGROFORESTRY SYSTEMS

A THESIS

BY

MD. MIJANUR RAHMAN

Registration No. 1405082
Session: 2014-15

Thesis Semester: January-June 2015

MASTER OF SCIENCE (MS)
IN
AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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Submitted to the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur in Partial fulfillment of the requirements for the degree of

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Approved as to style and contents by

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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGYUNIVERSITY, DINAJPUR
June 2015

DEDICATED

TO MY

BELOVED PARENTS

&

BROTHERS

ACKNOWLEDGEMENTS

First of all, the author expresses his sincere gratitude to the Almighty ALLAH The supreme rulers of the universe forever ending blessings for the successful completion of the present research work and to prepare the thesis.

The author express his deepest sense of gratitude and ever indebtedness to revered teacher and supervisor, Professor ***Dr. Md. Shafiqul Bari****, Chairman, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for ingenious suggestions, encouragement, guidance to complete this study and also for constructive criticism and meticulous review of the manuscript.*

The author sincerely express his heartiest respect, deepest gratitude and the profound appreciation to co-supervisor ***Dr. MD. Shoaibur Rahman****, Associate Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for co-operation and helpful suggestions to conduct the research work and in the preparation of this manuscript.*

The author expresses cordial thanks to National Science and Technology (NST) under the Ministry of Science and Technology (MoST) for funding of this experiment.

The author express his profound respect and gratefulness to ***Md. Hafiz All Amin*** *and* ***Md. Abu Hanif****, Assistant Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for co-operation, helpful suggestions to conduct the research work and in the preparation of this manuscript.*

The author wish to express deep sense to the Senior laboratory Technician Md. Iman Uddin and field worker Md .Abdul Quddus, Department of Agroforestry and Environment for their cordial co-operation.

Finally, The author express his most sincere gratitude to beloved parents, brother, sisters, friends, well-wishers, roommates and relatives for their blessings, inspiration and co-operation throughout the period of his study.

The Author

ABSTRACT

A field experiment was carried out in the Agroforestry and Environment Research Farm under the department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during November 2014 to March 2015 to observe the varietal performance of potato under litchi based Agroforestry system along with sole cropping. The experiment was laid out with two factors Randomized Complete Block Design (RCBD) following three replications. The treatments were, factor A: two production systems viz. S_1 (litchi + potato) and S_2 (Potato sole cropping); factor B: Eight potato varieties viz. V_1 (Diamond), V_2 (Cardinal), V_3 (Asterix), V_4 (Carage), V_5 (Lady Rosette), V_6 (Granula), V_7 (Raza) and V_8 (4.26 R). So, the treatments combinations were S_1V_1, S_1V_2, S_1V_3, S_1V_4, S_1V_5 ,S_1V_6, S_1V_7, S_1V_8, S_2V_1, S_2V_2, S_2V_3, S_2V_4, S_2V_5, S_2V_6, $S_2V_7$and S_2V_8. The total number of experimental plot was 48 and the size of each plot was 2mx2m=4m^2. The result of the experiment revealed that there was a significant effect of plant height, leaf length, leaf breadth, no. of leaf shoot^{-1}, no. of shoot hill^{-1}, no. of tuber hill^{-1}, weight of tuber hill^{-1}, yield plot^{-1}, dry weight, tuber grade hill^{-1} . In case of main effects of variety, the highest tuber yield (18.88 tha^{-1}) was recorded in the variety of Lady Rosette and the lowest tuber yield (12.29 tha^{-1}) was recorded in the variety of Diamond. In case of main effect of production system, the highest tuber yield per hectare (21.94tha^{-1}) was recorded in sole cropping of potato and the lowest tuber yield (8.43tha^{-1}) was found in Litchi+potato based Agroforestry system. From the economic analysis, it was observed that the higher BCR (3.50) was recorded in Litchi + Potato based Agroforestry system. On the other hand, the lower BCR (2.52) was recorded from the sole cropping of Potato. In case of interaction effect of the potato variety and production system, it was found that yield of potato varieties was lower when it was grown under litchi based Agroforestry systems, where as the yield was higher in sole cropping of potato. Moreover, among the eight potato varieties, Lady Rosette gave the better yield both in the litchi based Agroforestry systems as well as in sole cropping whereas the lowest yield was found in Diamond potato variety when grown in litchi based Agroforestry systems as well as in sole cropping. However, the suitability of the cultivation of different potato variety under litchi based Agroforestry systems may be ranked as Lady Rosette> Granula > Asterix > Carage> Raza > 4.26 R > Cardinal > Diamond.. Finally it may be concluded that out of the eightpotato varieties, Lady Rosette would be the best variety to be grown under litchi based Agroforestry systems considering the additional returns as per investment in terms of money and time.

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ABBREVIATION AND ACRONYMS

AEZ	: Agro-ecological zone
AFS	: Agroforestry System
AGF	: Agroforestry
BARC	: Bangladesh Agricultural Research Council
BBS	: Bangladesh Bureau of Statistics
BCR	: Benefit Cost Ratio
DAP	: Days after planting
DMRT	: Duncan's Multiple Range Test
MOP	: Muriate of Potash
MPTs	: Multipurpose Tree Species
N	: Nitrogen
RCBD	: Randomized Complete Block Design
TSP	: Triple Super phosphate
tha^{-1}	: ton/hectare
ha^{-1}	: per hectare
ha^{-1} $year^{-1}$	: per hectare per year
HSTU	: Hajee Mohammad Danesh Science And Technology University
MT	: Metric Ton
G	: Gram
Sq	: square

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Bangladesh is one of the densely populated countries of the world having an agro-based economy which situated in the North-Eastern part of South Asia with a tropical to sub-tropical climate. Now the population of Bangladesh is about 152.25 million in the area of 147570 sq Kilometers and growth rate is 1.37% per annum (BBS, 2013). The total forest area of the nation covers about 17% of the land (BBS, 2013). According to the Forest Master Plan and surveys conducted by multinational donor agencies, only 6% or a total of 0.769 million hectares land of the territory has actual tree coverage (Anonymous, 1999a). But to have benefits of the nature, any state should have at least 25% of her land covered with forests.

So, the population growth of Bangladesh and greater affluence exert pressures to convert forests to agricultural, industrial or residential land. Land use changes, together with the diversity in physical and socio-economic conditions in the uplands require new sustainable land use options for both livelihood security and environmental protection. The livelihood security of smallholders includes income security with market integration and local food production. FAO (2003) found that in all situations, people find suitable methods to adapt to the natural environment in which they live. The challenge for outsiders is to find methods to learn from the experience of the ethnic minorities and to apply their knowledge, gained in other social and environmental conditions, to foster the local development and research process. Because local knowledge is not static and cultural adaptation is continuous the methods developed must be dynamic, interactive and process-oriented. Under these fatal situations, various Agroforestry systems like fruit tree based Agroforestry system can address the stress of the day to considerable extents.

Agroforestry is a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers (Nair, 1979). As far the knowledge about the traditional Agroforestry is concerned, there has been fair understanding of various aspects involved therein (Lawson and Kang, 1990; Ong *et al.*, 1991; Gillespie *et al.*, 2000; Thakur and Dutt,2003; Thakur and Singh,2004). The Agroforestry technology play role in the light of combating hunger, poverty, diseases, environmental degradation is highly appreciable and ecological efficiency lead to increase in total production per unit of land (Garrity, 2004).

Agroforestry fruit tree based system can be defined as the planting system comprising combinations of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity. The system comprise of a combination of perennial fruit trees and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. Moreover, these systems incorporated a range of tree and crop species offers much more scope for useful management of light interception & distribution than monoculture forest and agricultural crops (Miah, *et al.,* 1995). The system utilize the interspaces between tree rows for intercropping with agricultural crops and this does not impair the growth and development of trees but enable farmers to benefit accrued from the use of fuel and timber from the trees (Singh, *et al.,* 2001). It provides conservation and improvement hass been one of the most important function of these system.

Again, Potato (*Solanum tuberosum* L.) is a tuber crop. It is herbaceous, succulent and dicotylentous plant with alternate stolons underground as well as alternate leaves on the stem above ground. It is originated in the Andes near the border of Peru and Bolivia in South America (Rowe and Randall, 1993). In Bangladesh cultivation of potato is started in the late 19^{th} century (Hashem, 1990). Potato is the world's fourth largest food crop, following rice, wheat, and maize (Li, 1985). This vegetable is one of the leading food crops and occupies the first position in both acreage and production among the total vegetables crop in Bangladesh (BBS, 2011). Compare to other roots and tuber and also many cereals crops, potato tuber have high ratio of protein to carbohydrates with ahigh nutritional value of the protein (Shekhawat *et al.*,1994). During 2013-14, the production of potato was 8950024MT from an area of 462032ha which is 4.03% higher than previous year and average yield was 19.371 MTha^{-1}(BBS, 2014). The crop can be used both as human food and as seed tuber. The food processing industries use potatoes for making chips, canned potato, starch and alcohol etc.(Khurana *et al.*, 2003). The average consumption of vegetables in Bangladesh is only 70 g per head per day including potato and sweet potato. Except tuber crops, it is only 30 g against the FAO recommendation of 200 g which is pretty below head/day. The low consumption of vegetables creates a tremendous pressure over cereals and also causes malnutrition leading to several kinds of health hazards. To provide balance diet there would be no alternative to produce vegetables, as this would also provide vitamins and minerals. But the scope of horizontal increase in production of potato is limited in the country mainly due to shortage of land and hence shady place can be used as an effective tool. But there are so many variety of potato in Bangladesh. We have no knowledge that which variety performs well on understory crops. So we need to investigate and find out best variety which grows well under shady place like under the plantation of fruit tree.

On the other hand, litchi (*Litchi chinensis*) is a major fruits of Bangladesh especially, in northern part due to its edapho-climatic adaptability, wide growing area and adaptability with regional variation. In the northern part, the litchi is an integral component of homestead gardening. However, day by day litchi orchards are increasing and get preference by the farmers. Farmers already started to grow potato under litchi tree. But they do not know which variety give more yield and as well as economic benefits. So, we should develop some protocol and findings, which are beneficial for the litchi gardener and potato growers. Keeping in view the manifold advantages associated with integration of potato and litchi into Agroforestry production system, a study was initiated with litchi as upper-storey and eight potato varieties as ground-storey components with the following objectives:

- To find out the performance of potato in the floor of Litchi (*Litchi chinensis*) orchard
- To identify the suitable potato variety for litchi based Agroforestry system
- To determine the interaction effect of production system and potato variety as well as the economic analysis of the production

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CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Huge amount of literature is available where efforts have been made to understand various aspects of Agroforestry systems, although information is inadequate with respect to the components in Agroforestry systems. Keeping this in view, an attempt has been made to review findings on Agroforestry practices with particular emphasis on potato in association with litchi tree. The relevant literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Benefits from Agroforestry system

2.2 Effects of Light on plant growth and development

2.3 Agroforestry system based on vegetable

2.4 Agroforestry system based on fruit tree

2.5 Agroforestry systems based on litchi

2.6 Agroforestry systems based on potato

2.1 Benefits from Agroforestry system

Pandit*et al.* (2014) stared that Agroforestry has been recognized as one of the important systems for supporting the livelihoods of a large number of rural farmers in the Nepalese hills. However, its conservation and socio-economic values have received little attention. This resulted in increased livelihood benefits to local people. Production of goat meat and buffalo milk has increased considerably. The high economic benefits are mainly associated with the introduction of various fodder trees and grasses in private farmlands. It is concluded that the various drivers of the Agroforestry system need to be carefully attended so as to improve both positive conservation and livelihood outcomes. Enabling policy and practices are needed to initiate and support farming cooperatives in the commercialization of Agroforestry products and market the conservation values in a changing climate.

Korwar *et al.* (2014) stated that Agroforestry in rainfed areas increases livelihood security through simultaneous production of food, fodder, and firewood, and an increase in total productivity per unit area of land. To enhance rural livelihood security among the dryland farmers, several improved Agroforestry systems, commercial plantations and biofuels and bioenergy systems came into being for adoption. Agroforestry plantation-based success stories reveal livelihood security of small, marginal, and landless farmers. Steps to promote basic and promotional Agroforestry research in dryland agriculture and appropriate policy responses with extension outreach may potentially deliver better results in rainfed agriculture. Rainfed Agroforestry for livelihood security reflects the positive way in utilization of rainfed area resources.

Rahman *et al.* (2012) stated that in the Padma floodplain of Bangladesh, the traditional system of agriculture has become unsustainable due to high population growth. Mango-based Agroforestry which has been practiced by the farmers since the 1990s, is a promising alternative and is considered as one of the few options to lift farmers out of poverty and improve livelihood security. Farmers with the least land were found to allocate a higher percentage of their land to Agroforestry, and the increased income from Agroforestry compared to other agricultural systems helps reduce relative poverty. This income maintains basic household needs, providing food security and fuel wood, and contributes to healthcare, housing and sanitation conditions, and meeting educational expenses.

Magcale-Macandog *et al.* (2010) stated that the impact of Agroforestry on food security of upland farmers is least recognized and appreciated given that the linkage between them is quite complex and not well understood. The crucial role of Agroforestry in enhancing food supply and augmenting family income is commonly ignored. Fruits from perennial crops and trees served as secondary food crops especially during lean months of food supply. The last major finding was that the adoption of Agroforestry significantly increased the level of benefits by around 42–137%, compared with the low income from continuous annual monocropping. The key to making upland farm households food secure is to increase the productivity of their farms and home gardens.

Jose (2009) stated that Agroforestry systems are believed to provide a number of ecosystem services; however, until recently evidence in the Agroforestry literature supporting these perceived benefits has been lacking. This special issue brings together a series of papers from around the globe to address recent findings on the ecosystem services and environmental benefits provided by Agroforestry. As prelude to the special issue, this paper examines four major ecosystem services and environmental benefits of Agroforestry: (1) carbon sequestration, (2) biodiversity conservation, (3) soil enrichment and (4) air and water quality. Past and present evidence clearly indicates that Agroforestry, as part of a multifunctional working landscape, can be a viable land-use option that, in addition to alleviating poverty, offers a number of ecosystem services and environmental benefits. This realization should help promote Agroforestry and its role as an integral part of a multifunctional working landscape the world over.

Brodt *et al.* (2009) stated that although hedgerows, windbreaks, and other biodiversity-enhancing farm edge features offer the potential for ecosystem benefits without occupying much crop space, relatively few farms in California, USA include such features. We also identified social, economic, and agronomic incentives and constraints to installing biodiversity-enhancing edge features. More than one-third of the study farmers had installed native hedgerows, windbreaks, and/or grassed edges. Interviews demonstrated the importance of socially influential farmers working in tandem with public and private agencies to build initial interest in these practices. However, these features occupied less than four percent of all possible edge length. Constraints to increasing adoption included high costs, fear of harboring weeds and rodents, and lack of certainty about ecosystems benefits, highlighting the need for cost-share programs and more regionally-focused agro-ecological research

Gruenewald *et al.* (2009) stated that two Agroforestry systems were established on reclaimed mine sites in NE-Germany (Lusatia) and Central Germany (Helmstedt). The yield potential and the sustainability of yields were studied for different clones of poplar (*Populus* spp.), willow (*Salix viminalis* L.), and black locust (*Robinia pseudoacacia* L.), considering different rotation periods (3-, 6-, and 9-year-rotation) and approaches of soil amelioration (mineral fertilizer, compost). In the Agroforestry system in Lusatia, special emphasis was given to the interaction between trees (*R. pseudoacacia*) and crops (*Medicago sativa* L.). Considering the land equivalent ratio (LER), *R. pseudoacacia* hedgerows have practically no negative influence on yields of *M. sativa*. Hence, with regard to an increasing demand for woody biomass, alley cropping with *R. pseudoacacia* and crops such as *M. sativa* may provide a promising alternative for future land use in the temperate zone

Godsey (2005) and the National Agroforestry Center (2003) investigated the funding incentives available through the federal, state and non-governmental organizations (NGO) for the five Agroforestry practices. Cost sharing was found to be the most commonly used incentive. Other incentives such as producer grants, land rental payments, financial incentive payments and technical assistance were also identified. Most federal funding available for Agroforestry practices is distributed through the United States Department of Agriculture (USDA), while the state of Missouri funding is available through the Missouri Department of Agriculture (MDA).

Sun *et al.* (2008) have been studied the economics of hedgerow systems and results look very promising. Most studies cite the number one initial effect of hedgerow systems being an increase in productivity from the start. This is achieved through a stabilized moisture regime, and the 23 increased soil fertility has benefits alluded to previously. One study showed yields of maize increasing up to 22 percent without fertilizer addition, and up to 70 percent increase with fertilizer use

Dorr (2006) found a lifestyle attitude that is represented as “loss of trees as a problem” to be interested in the Agroforestry practices except for windbreaks where it was found not significant. These result shows that attitudes are not the most important factor influencing conservation practices but play an important role in whether there is interest in new practices.

University of Missouri Center for Agroforestry Training Manual (2006) study the windbreaks protect crops from wind erosion and enhance wildlife habitat. This practice improves air quality through wind speed reductions and the physical capture of airborne particulates including dust, smoke and odors; provide aesthetic diversify by adding trees in an agricultural landscape. Riparian buffers help to reduce runoff and non-point source pollution, stabilize stream banks, improve aquatic and terrestrial habitats. Alley cropping can reduce soil erosion from wind and water.

Brandle *et al.* (2004) listed the following economic benefits of Agroforestry:

1. When various species are included in the design, they can contribute directly to the production of nuts, fruits, timber and other wood products. This helps to diversify and increase farming income while also providing a stock of capital in valuable timber.

2. When used in livestock production systems, they improve animal health, improve feed efficiency and contribute to the economic returns of producers.

3. The practices can also help to reduce energy consumption by the farm and improved working conditions within the farm area, which helps to save cost and increases productivity.

4. Agroforestry technology can reduce costs of production, increase productivity and provide multiple outputs.

Alavalapati *et al.* (2003) stated that Agroforestry systems (AFS) provide a mix of market goods and nonmarket goods and services. We postulate that if nonmarket goods and services can be internalized to the benefit of landowners, the adoption of AFS will increase. It has been found that the profitability of silvopasture would increase, relative to conventional ranching, if environmental services are included. Estimates of public willingness to pay for environmental services associated with silvopasture and estimates of ranchers' willingness to accept for the adoption of silvopasture will provide a scientific basis for policy development.

Batie (2001) research has shown that firms and individuals rarely practice sustainable Agroforestry activities, and that the rate of participation in the incentives programs is low. The following have been identified as constraints of government programs: inadequate funding, the lack of problem targeting, lack of tailoring to specific circumstances, the complexity of the programs, and the reduced capacity of agencies to deliver such programs. These have been the criticisms of farmers and ranchers on existing farm bill conservation programs.

2.2 Effect of Light on plant growth and development

Sharif *et al.* (2010) conducted a field experiment at the Agroforestry Farm, Department of Agroforestry, Bangladesh Agricultural University, Mymensingh during July 2010 to November 2010 to find out the effect of shading times (i.e. morning shade, noon shade, afternoon shade and shade free) of different trees (Akashmoni, Eucalyptus and Jhau) on growth and yield of transplanted aman rice (cv. BRRI dhan 30). Highest plant height of rice (126.667 cm) and lowest 1000- grain weight (21.247 g) and grain yield of rice (2.967 t ha^{-1}) was observed in the noon shade area of Akashmoni. Highest 1000-grain weight (35.363 g) and grain yield (6.197 t ha^{-1}) of rice was found in shade free area of Jhau which was statistically similar to grain yield (5.232 t ha^{-1}in the afternoon shade area of Jhau. Biological yield of rice was found lowest (6.877 t ha^{-1}) Lowest grain yield reduction and maximum grain yield was found in the shade free area of Jhau which was statistically similar to grain yield in the afternoon shade area of Jhau. So, in consideration of shade casted by different trees, Jhau-Aman rice based system is found more suitable than Akashmoni and Eucalyptus tree rice based Agroforestry) in the noon shade area of Akashmoni; where highest (13-397 tha^{-1}) was observed on the shade free area of Jhau system.

Khatun *et al.* (2010) conducted an experiment at the Germplasm Center (GPC), Bangladesh Agricultural University, Mymensingh during December 2008 to November 2009 to investigate the growth and development of some medicinal plants (Aloevera, Asparagus and Misridana) under multistoried Agroforestry systems having three light levels i.e. open condition (received 100% of light), guava + lemon based Agroforestry system (received 55-60% light) and sissoo + lemon based Agroforestry system (received 45-55% light). The experiment was laid out in a randomized complete block design with three replications. Results revealed that the performance of three medicinal plants, Aloevera, Asparagus and Misridana in terms of growth, yield contributing characters and yield was significantly influenced by the multilayered Agroforestry systems. Growth and development, yield contributing characters and yield of Aloevera, Asparagus and Misridana were greater in all the Agroforestry systems than open condition. However, between two Agroforestry systems (guava + lemon and sissoo + lemon based systems), Aloevera and Misridana performed better under guava with lemon Agroforestry system than sissoo with lemon Agroforestry system in terms of growth, yield contributing characters and yield except leaf dry matter percentage for Aloevera and corms dry matter percentage for Misridana. On the other hand, Asparagus performed better in respect of growth, yield contributing characters and yield under sissoo + lemon based Agroforestry system than guava + lemon based Agroforestry system.

Bellaloui *et al.* (2012) stated that the cause of poor seed quality (germination) of soybean produced in the Early Soybean Production System in the mid- south USA is still not completely understood. Temperature, solar radiation, and soybean genotype may all be involved seed composition, mineral level, and nitrogen as- similation in high and low germinability soybean plant introductions in a full-sunlight (unshaded) and a low-light inten- sity (shaded) environments. Shade netting was employed in field plots that reduced light intensity by about 50% and air temperature by about 10°F/6°C (10%). A two-year field experiment was conducted on soybean accessions with high germinability (PI 587982A and PI 603723), low germinability (PI 80480 and PI 84976-1), and on soybean cultivars (DSR-3100 RR STS and Pella 86). Results showed that shade resulted in higher total oil, linoleic and linolenic acids, and lower protein and oleic acid. Shade also resulted in lower nitrogen assimilation, leaf chlorophyll concentration, but unshade resulted in higher total seed boron, iron, and nitrogen concentrations. Seed structural boron was positively correlated with germination and protein. Structural boron percentage was consistently higher under shade than under un- shade in PI 80480, PI 84976-1, DSR-3100 RR STS, and Pella 86, but consistently higher under unshade than under shade in higher germinability lines PI 587982A and PI 603723, suggesting that different distribution mechanisms of structural boron exist between genotypes. The positive correlation between germination and structural B and between protein and structural B signify a possible role of B in seed quality traits. Our research demonstrated that light intensity, combined with temperature, can alter seed constituents. Higher germinability lines had higher germination rates and lower percentages of hard seed, desirable traits for soybean seed.

Thakur and Singh (2002) in a recently conducted study in *Morus* based Agroforestry system reported that solar radiation transmission through unmanaged canopies of 5 year old *Morus* trees was 9.6 per cent. However, 25 %, 50 % and 75 % crown removal allowed 21.6; 36.8 and 52.7 per cent transmission of photo synthetically active radiation beneath canopies, respectively. Solar radiation transmission between 9- 36.8 per cent have adversely affected yield of both urd and pea.

Li *et al.* (2002) measured the transpiration of *Malus domestica* by the heat pulse method and evaluated it in relation to a variety of environmental parameters in orchard settings in Israel. Transpiration increased with temperature and vapor pressure deficit, and decreased with increasing humidity. Additionally, with reduced air temperature and no change in absolute humidity, declines in vapor pressure deficits and relative humidity may occur. This can result in greater water use efficiency in some situations.

Marsal *et al.* (2002) stated that transmittance of individual tree canopies (more indicative of below-crown light levels) was in the range of 40 to 60% incident PAR. This study, with radishes (*Brassica* spp.) as the understory crop, provided land equivalency ratio

(LER: equation 3.2) values of 1.5 28 to 2.01 for saleable radishes. No yield depression of the pear was observed during the two-year study (Newman, 1983). Another study of pear, focused on water use, noted that canopy radiation interception within the orchard at mid-day was approximately 38% of incident.

Singh *et al.* (2001) observed that the effect of three tree species namely eucalyptus (*Eucalyptus teretcorris*), acacia (*Acacia nilotica*) and poplar (*Populus deltoides*) on the performance of turmeric (*Curcuma longa* L.) was investigated in Kamal, Haryana, India. The mean germination of turmeric was maximum when grown in association with acacia and minimum in the control i.e. in open field. The mean height attained by turmeric after 90 days was highest under eucalyptus and lowest under poplar. The yield of turmeric was in the order: eucalyptus > control > poplar > acacia.

An experiment was conducted by Paez *et al.,* (2000) to evaluate the effect of light on the growth of *Aloe vera.* The plants were vegetatively propagated and grown under full sun, partial sun (30% of full sun) and deep shade (10 % of full sun) for 12-18 months. After one year of growth, plants grown under full sun produced more numerous and larger axillaries shoots, resulting in twice the total dry mass than those under partial shade. The dry mass of plant grown under deep shade was 8.6% more than that of plants grown under full sun. partial shade increased the number and lenth of leaf produced on the primary shoot, but leaf dry mass was still reduced to 66% and 13% respectively of that under full sun in case of *Asparagus racemosus*.

Onwueme and Johnston (2000) investigated that shading often occurs under normal growing conditions in various cropping systems (for example, intercropping, alley cropping), field experiments were carried out to determine the effects of shading on stomatal density, leaf size, leaf dry matter, and leaf lamina thickness in the major tropical root and tuber crops, tannia (*Xanthosoma sagittifolium*), sweet potato (*Ipomoea batatas*), yam (*Dioscorea esculenta*), cassava (*Manihot esculenta*), and taro (*Colocasia esculenta*). Shading decreased stomatal density in the lower epidermis of tannia, sweet potato, yam and cassava, and in the upper epidermis also in tannia and sweet potato; the upper epidermis of yam and cassava were devoid of stomata. In contrast to the other species, taro under shade had an increased stomatal density in both the upper and lower epidermis, a finding which was confirmed in subsequent pot experiments. This response of taro was postulated as a possible manifestation of greater shade adaptation by the species.

One critical issue, reviewed by Black and Ong (2000) is that radiation use efficiency can vary substantially depending on when it is measured, the degree to which appropriate measures of interception are used, and the nature and extent of other limiting factors.

In Burkina Faso, Jonsson *et al.* (1999) found that the dominant fruit trees in the region, *Parkia biglobosa* (néré) and *Vitellaria paradoxa* (karité) reduced mean understory soil temperatures 1 to 2 degrees. An important effect of shading was that the amount of time when the understory temperature was greater than 40 EC was reduced from 27 hours per week in full sun to between 1 and 9 hours in shaded conditions.

Johnston and Onwueme (1998) investigated that plants of yam, taro, tannia, cassava and sweet potato were raised under shade or in full sunlight and the effect of shade on leaf chlorophyll and carotenoids was examined to determine and compare the relative shade tolerance and adaptability of the various species. All five species of root crops adapted to shade. The chlorophyll concentration was higher, while the chlorophyll *a:b* ratio, carotenoids per unit chlorophyll and the weight per unit area of leaf were lower in the shade than in the sun in yam, tannia, taro, cassava and sweet potato. All species had larger leaves and more chlorophyll per leaf in the shade. The extent of the changes, however, differed between species. The aroids (taro and tannia) appeared to be shade-tolerant species as their chlorophyll *a:b* ratios changed less than those of the other species in the shade, suggesting that their light-harvesting systems may be normally adapted to shade conditions. Taro and tannia also adapted to shade by a greater proportional increase in leaf size, a smaller reduction in leaf weight per unit area and a greater proportional increase in chlorophyll and carotenoids per leaf than the other species. Yam compensated for shade by having a large proportional increase in leaf size and appeared to be moderately tolerant of shade. Sweet potato and cassava appeared to be the least tolerant of shade of the major tropical root crops.

Singh (1997) investigated that Maize, Sorghum, Green gram (*Vigna radiate)*, groundnut and okra were unshaded, shaded to 65% normal light at ambient temperature (33°C or 38°C + high humidity). With the exception of okra where seed yield was not affected, shading decreased grain or seed yield in the other crops. Shading combined with high temperature and humidity resulted in failure in grain formation in maize and sorghum, and produced parthenocarpic fruit in okra. Green gram seed yield was decreased further but that of groundnut was not it.

Miah *et al.* (1996) stated Agroforestry system incorporate a range of tree and crop species offer much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops but the competition in Agroforestry system, ultimately crop yield is dependent upon the partitioning of resources, primarily of light and water between tress and crops.

2.3 Agroforestry system based on vegetable

Panwar and Wani (2014) conducted a field experiments during the kharif seasons of 2012-14 at the forest nursery and research center, College of Forestry, Allahabad Agriculture Institute, Deemed University, Allahabad, on growth and productivity of Ipomoea batatas under poplar based Agroforestry system. The experiment was laid out in shade (under trees) condition with 7 treatment replicated thrice in Randomized Block design. A sweet potato variety known as Pusa Red was used for the study. The vine cutting of 15 cm length with 4-6 nodes of Pusa Red variety of sweet potato were planted in spacing 45cm × 60cm. Nitrogen, Potash, and Phosphorus was applied in form of organic manure Farm yard Manure, Vermicompost, and Neemcake. T3 (vermicompost) recorded highest survival percent , length of vine, number of branches/vine, shoot fresh weight, shoot dry weight, tuber yield/plot, number of tuber per plot under poplar trees. The maximum Gross return was noticed in T3 with Rs. 99204.00. The maximum Benefit cost ratio was noticed in T3 with 1:1.37

Harterreiten-Souza *et al.*(2014) stated that the integration of Agroforestry plots with ephemeral crops such as vegetables on the farm scale can probably serve as a refuge and source of beneficial insects. Therefore, Agroforestry systems possibly represent an alternative that favors ecosystem services and help growers in the transition process from conventional to agro-ecological agriculture. Field surveys showed that Agroforestry systems can harbor more species than horticultural crops, independent of the functional group. They also contain a greater diversity of herbivores and an even greater diversity profile of natural enemy communities. Agroforestry systems served as a source of natural enemies that can colonize horticultural crops when herbivores are present.

Mir and Khan (2008) stated that an experiment upon an agri-silvicultural system involving Willow (*Salix alba*) tree, Kale (*Brassica oleracea* var. *acephala*) and Knol khol (*Brassica oleracea* var. *caularapa*) was laid in randomized block designed at farmers' willow field at Shalimar near Sher-e-Kashmir University of Agricultural Sciences and

Technology of Kashmir, Srinagar India during 2005 and 2006. The main plot was divided into sub-spots with 8 m × 2 m in size each in which four two-year-old willow (*Salix alba*) trees were at a spacing of 2 m × 2 m in a sub-spot. The intercrops were maintained at recommended spacing and supplied with recommended doses of fertilizers. The benefit-cost ratio in willow plantation intercropped with vegetable crops of Kale and Knol Khol was analyzed and compared with the benefit-cost ratio of sole willow tree forestry. The results showed that every rupee invested in plantation of agri-silvicultural system generates benefit-cost ratio of 2.78 and 2.79 in case of Willow intercropping with Kale and Willow with Knol khol, respectively, while as for sole crop of willows benefit-cost ratio was calculated to be 2.66. These results provided circumstantial evidence in favour of adopting Agroforestry involving willow instead of Sole tree forestry

Hossain *et al.* (2005) carried out an experiment to evaluate the performance of Indian Spinach grown under Eucalyptus tree in different orientation from May to August 2003 at the Bangladesh Agricultural University, Mymensingh. The treatments involved different orientation: north, south, east and west for each of the tree. The fresh yield produced in south orientation followed by west, east and north, 56.37%, less than the open field and that of for dry yields were 52.74, 56.41, 58.14 and 59.80% less respectively.

Samsuzzaman *et al.* (2002) carried out three studies in Bangladesh to find out the effect of tree species on crops and alternative management practices for better system productivity. The first experiment revealed that the highest yield of mustard (0.788 t/ha) and rice (2.89 t /ha) was obtained under *Albizia lebbeck* trees and *Acacia nilotica*, respectively. The result of the second experiment indicated that the lower reduction in yield of adjacent crop with wider the tree spacing the result of the third experiment showed that root and shoot pruning increased the grain yieldof wheat by 22%. The highest increase in the yield of rice (27%) and radish (72%) were obtained due to pruning of *Acacia nilotica* two and three times a year respectively. Pruning of *Albizia lebbeck* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields

An field experiments was conducted by Meerabai *et al.* (2001) during 1998/99 and 1999/2000 at Vellayani, Kerala, India to investigate the effects of N (50, 100, 150 and 200 kg/ha), P (0, 50, 100 and 150 kg/ha) and K (0, 50,100 and 150 kg/ha) applied at different combination, on the yield of ginger intercropped under partial shade of coconut.

Yield increased with the increasing rate of each fertilizer. Treatment with 15kg N/ha + 50kg P/ha +150kg K/ha resulted in the highest average fresh rhizome yield (18.4 t/ha), net return (Rs. 148000/ha), and benefit: cost ratio (2.35).

Rashid (1999) examined the cabbage (Brassica oleracea var. capitata L.) is an important winter vegetable crop of Bangladesh. The climatic adaptability of the crop is so wide that its commercial cultivation is possible over a wide range of temperature, varying from 5 to 21^0c. A long period of cold treatment induces the plants to bolt sooner and flower more abundantly. In Bangladesh, winter is very short but is long enough for cabbage heads to mature. In 96-97, total production of cabbage was 106655mton from 26425 acre land which was the third highest production of winter vegetable in Bangladesh of that year.

2.4 Agroforestry system based on fruit tree

Hasanuzzaman *et al.* (2014) stated that cropland Agroforestry is an important production system in the southwest region of Bangladesh. This study focused on the floristic composition and management of existing cropland agroforests. A total of 313 cropland agroforests were surveyed and 83% respondents practiced pure Agroforestry while the remaining 17% practiced Agroforestry with fisheries. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 species of agricultural crops were from 28 families. A higher proportion (79%) of cropland agroforests were occupied small land areas (0.12–0.80 ha). About 63% of respondents planted trees for fruit production and 47% for timber production, and 35% of respondents engaged in commercial production (35%). *Swietenia macrophylla* was the most prevalent species (relative prevalence 20.83) followed by *Mangifera indica* (relative prevalence 15.57) and *Cocos nucifera* (relative prevalence 7.08). Shorter spacing was used for timber and fuel wood species and wider spacing for fruit trees. A wide range of rotation periods, from 5 to 25 years, was observed for both cases.

Dhakal *et al.*(2012) stated that Agroforestry-based farming systems evolved in the Dhanusha district of Nepal following the conversion of forest into agriculture during the early 1950s. The experts' discussion resulted in a scale to differentiate the prevailing farming systems in the study area considering five key components of Agroforestry: agricultural crops, livestock, forest tree crops, fruit tree crops and vegetable crops. The study reveals that land use had generally changed from very simple agriculture to Agroforestry, triggered by infrastructure development, technological innovations, institutional support (subsidies and buy-back guarantees) and extension programs. The three types of Agroforestry systems, which are the focus of this study, varied significantly in terms of farm size, cropping intensity, use of farm inputs, tree species diversity, tree density, home to forest distance and agricultural labour force.

Rahman *et al.* (2010) conducted a field experiment at the Bangladesh Agricultural University germplasm center, fruit tree improvement project (FTIP), Department of Horticulture, Bangladesh Agricultural University, Mymensingh, during July to November, 2008 to find out the performances of tomato under different multistoried Agroforestry production system and open field condition. Different multistoried Agroforestry system such as Amloki + Guava based agrofrestry system (T_1), Horitaki + Lemon based Agroforestry system (T_2) and Bohera + lemon based Agroforestry system (T_3) were investigated in the study. Tomato was grown following the RCBD design with three replications. The study showed that except plant height all others morphological characters viz. Number of branches per plant, number of leaves per plant, number of fruits per plant, fruit length, fruit diameter and single fruit weight were highest in open field condition among the different Agroforestry systems (Multistoried vegetation), highest yield was obtained in Horitaki + lemon + tomato based Agroforestry system, which was 16.67% lower than open field condition.

Ali *et al.* (2010) conducted a field experiment to evaluate the performance of four Cane species under different multipurpose tree species. The treatments were three tree species viz. Mehogony, Deshi neem and Eucalyptus, which were used as the upper storey. There was also a control (Open field) treatment. Four cane species namely Bhudum beth, Udum beth, Jali beth and Golla beth were used as the middle storey non-woody perennial. He aim of the experiments was to study the growth performance and selection of potential cane species under different multipurpose tree based Agroforestry system. Considering cane species, jali beth was the best performer compared to other cane species. Udum beth + Deshi Neem were found as the best combination followed by Udum beth + Mehogony combination and Udum beth + Eucalyptus combination. Significantly the lowest peformance was found in open field irrespective of cane species. While the tree effects, Mehogony was the best one followed by Deshi neem and significantly the poorest performance was found in the open field.

Singh (2007) studied that pure guava cultivation was an old concept; utilization of its interspace with traditional cropping system was profitable in Gangetic region of Uttar Pradesh. The farm families of Mainpuri, Etah, Budaun, Hardoi, Farrukhabad, Kannauj, Unnao, Kanpur Nagar, Lucknow, Sitapur and Allahabad adopted the cultivation of wheat, potato, vegetable pea, cucurbits, onion, summer moong, summer urd, okra, sweet potato and barley as parallel crops in association of guava plantation. At the initial stage, guava fruits was 150-250 q/ha while, wheat, potato, vegetable pea, cucurbits, onion, summer urd/moong, okra, sweet potato and barley yielded 30, 220, 95, 180, 235, 6, 80, 190 and 32 q/ha, respectively, with protective irrigation.

Islam (2005) conducted an experiment to investigated the performance of lemon and guava grown under coconut multistoried Agroforestry system and observed a significant influence on yield, yield attributing and quality parameters of lemon as well as guava. The best yield of lemon was found in the coconut + lemon based Agroforestry system while the highest yield of guava was obtained from the open conditions.

Bellow and Nair (2003) surprisingly found in comparison to other types of trees, the research conducted on fruit trees in the areas such as tree-crop interactions and the appropriate horticultural and agronomic management regimes needed to optimize total yields of mixed systems in particular biophysical and social environments are extremely scarce. An exception is for those fruit trees such as *Coffea* spp. or *Theobroma* spp. grown as understory species where the tree is treated more like the annual crop component and the tree component is more frequently from the timber category. Research similar to historical agronomic and horticultural research is needed to identify optimal stand densities, fertilization regimes, and planting and management practices in fruit-tree based Agroforestry systems in order to maximize the benefits that these systems will produce.

McDonald *et al.* (2003) study the farmers in Jamaica's Blue Mountains reported interest in planting trees on their farms; their preferred trees were described as multipurpose trees with fruit as one of their products and the majority of existing trees were fruit trees.

Briggs and Twomlow (2002) study in Southern Uganda, *Musa* spp. was the dominant perennial managed on farms and farmers generally allocated land to this herbaceous perennial in a ratio of 2:1 versus annual crops such as maize (*Zea mays* L.) and bean (*Vigna* and *Phaseolus* spp.).

Osei *et al.* (2002) have undertaken an experiment to compare the merits of four cacao-coconut intercropping systems with the traditional cultivation of cacao under *Gliricidia sepium* shade at the Cocoa Research Institute of Ghana. Cacao seedling girth was not affected when intercropped with coconut but was significantly (P=0.01) reduced when intercropped with *G. sepium*. High density cacao facilitated better early canopy formation. Yield of cacao spaced at 2.5 m triangular (1739 plants ha^{-1}) with coconut at 9.8 m triangular (105 plants ha^{-1}) was significantly higher (P=0.05) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cacao spaced at 3 m × 3 m showed better flowering and gave higher coconut yields, but cacao spaced at 2.5 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture stress was the greatest in cacao system with *G. sepium* shade and this could be responsible for the low yield of cacao in that treatment. It is suggested that properly arranged high density cacao under widely spaced coconuts can be a profitable intercrop system for adoption by cacao farmers in Ghana.

Ceccolini (2002) study in Soqotra Island, a remote location near the Yemeni coast, the presence of fruit trees appeared to be most closely related to subsistence, as opposed to market gardening. The number of large fruit trees declined as the importance of crops destined for the market increased, highlighting the potential importance of the income generating aspects of fruit-tree management and the relative value of the various products.

Mendez *et al.* (2001) found that Nicaraguan homegardens had 37% of their total space allocated to fruit producing species, on average; moreover, 85% of the fruits so produced were for home consumption and the remainder for marketing. When farmers in Jamaica were questioned as to the importance of trees, fruit was given as the second most important product following timber.

Quartieria *et al.* (2002) investigated the competition effects with fruit trees, it is important to take into account the multi-year nature of growth cycles and responses. For pear, it was shown 32 that N taken up at or after harvest was preferentially used during the following year for growth and fruiting.

Korikanthimath *et al.* (2000) conducted an experiment at Sirsi, Karnataka during 1992-95 to explore the possibility of cultivating cardamom (*Elettaria cardamomum* Maton) as a mixed crop with coconut. The average size of coconut holdings is as low as 0.22 ha and

98% of the holdings are below 2 ha. The results revealed that tall coconuts and short cardamom plants with varying rooting patterns and spacings intercepted solar energy at different vertical heights, and their roots (rhizosphere) absorbed nutrients and soil moisture at different depths and lateral distances. The coconut canopy provided adequate shade for shade-loving cardamom in this multi-storeyed cropping system. Intercropping with cardamom reduced coconut yield compared with coconuts in monoculture (mean values of 85.7 compared with 91.3 nuts/palm), but intercropping with high value cardamom increased overall profits (cardamom yields in 1993-94 and 1994-95 were 15.66 and 554.2 kg/ha, respectively).

Salam *et al.* (2000) investigated the food production from trees was categorized as "not important" by only 15.1 % of farmers in this study while generation of household income was cited as very important by 87.8 %; ecological functions of trees in the landscape were scarcely considered. The availability of labor to establish and care for trees and the potential conflict between agricultural production and tree establishment were noted as important constraints.

In a field trial conducted during 1994-95 and 1995-96 by Hegde *et al.* (2000) to investigate the performance of ginger cv. Suprabha grown as intercrop in an adult arecanut plantation (30-year-old) at the Agricultural Research Station (Pepper), Sirsi, Karnataka, India, and its performance was compared with those planted under open conditions. Ginger plants grown as intercrop were significantly taller than those under open conditions (pure crop) when measured 200 days after planting and had significantly lower number of functional leaves and tillers per clump. Interception of photosynthetically active radiation (PAR) by ginger was maximum at 110 DAP, both in open conditions (1.088 ly/min) and in the intercrop (0.788 ly/min). Percentage of PAR intercepted by ginger out of total PAR was the lowest at 170 DAP in both open (74.4%) and under arecanut shade (56.41%). Mean duration of ginger crop grown in open conditions was 184.5 days, while it was 198.5 days when grown as intercrop. Per plant yield of ginger under arecanut plantation was significantly higher (154.5 g) when compared to open conditions (118.8 g/plant). Individual rhizomes of ginger grown in arecanut plantation were slightly bigger (4.5 g/rhizome) than the crop grown in open (3.4 g/rhizome). Yield of arecanut was not affected due to intercropping with ginger during the two years study. However, there was slight improvement in the yield of arecanut (3.20 kg chali/palm) when compared to monocropping of arecanut (2.59 kg Chali/palm).

2.5 Agroforestry systems based on litchi

Zaman (2014) conducted a field experiment at the Agroforestry and Environment Research Field, Hajee Mohammad Danesh Science and Technology University, Dinajpur to investigate the potentiality of three napier fodder varieties under Litchi (*Litchi chinensis)* orchard.: the variety was BARI Napier -1 (Bazra), BARI Napier - 2, (Arusha) and BARI Napier -3 (Hybrid) and concluded that the cultivation of Bazra napier variety in the floor of Litchi orchard ensures higher revenue to the farmers compared to its sole cropping.

Sarker (2012) conducted an experiment in the farmer's litchi orchard in Jorkali of Biral upazila under Dinajpur district to investigate the performance of turmeric under Litchi (*Litchi chinensis*) orchard and concluded that BARI 1 termeric variety is the best for production in association with litchi based Agroforestry system.

Hanif *et al.* (2010) conducted a field experiment at the Agroforestry Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during 08 January 2009 to 08 April 2009 to evaluate the performance of Okra plant under litchi based Agroforestry system. The treatments were three okra variety viz. hybrid okra variety, BARI-1 and local okra variety, which were used as ground layer crop. There was also control (sole cropping) treatment. This experiment was laid out using two factors Randomized Complete Block Design (RCBD) with three replication. The aim of the experiments was to study the growth performance and selection of potential okra variety under litchi based Agroforestry system. The yield contributing parameters were maximum in sole cropping of hybrid okra. The yield was highest (10.24 t ha^{-1}) in monocropping of hybrid okra and the lowest yield (4.24 t ha^{-1}) was found in T_6 (Litchi + Local okra variety). But the litchi based Agroforestry system ensures higher return and more sustainable than sole cropping. The suitability of okra variety may be ranked as Okra hybrid variety > BARI-1 okra > Local okra variety.

Uddin *et al.* (2010) conducted a field experiment at the Litchi-Pineapple based Agroforestry Farm, Hajee Mohammad Danesh Science and Technology University during April 2007 to June 2007 to examine the growth performance of Indian spinach grown in association with pineapple at different orientations of litchi tree. There were five treatments consisted of 4 different orientations (north, south, east and west) of litchi tree for production of Indian spinach and one control plot. The aim of the study was to detect the orientation effect of Litchi -Pineapple based Agroforestry system on the yield performance of Indian spinach. The longest plant of Indian spinach was recorded in east orientation. The values of all other parameters were found highest in open field (full sun light). Significantly the highest yield (7.12 tha^{-1}) of Indian spinach was recorded in open field followed by south orientation (6.60 tha^{-1}) while the lowest yield (5.80 tha^{-1}) was found in the east orientation. Moreover, the results indicate that, the Litchi -Pineapple based Agroforestry system have the potentiality for producing Indian spinach as Agroforestry production concept.

Miah *et al.* (2010) conducted a field experiment to investigate the performance of papaya and ginger grown as understorey crop under litchi at different distance on the yield and yield contributing characters at BADC farm, Dinajpur during April to December 2004. Two varieties of papaya (Shahi=V_1 and Rachi=V_2) and a local variety of ginger were grown at four different distances from litchi tree namely D_1=Control/outside the litchi canopy (100% PAR), D_2= 1.5m distance (25-35% PAR), D_3= 3m distance (55-65%PAR) and D_4= 4.5m distance (80-90%PAR). Among the two papaya varieties Shahi produced the highest yield (19.96 t/ha) due to the increasing of fruit number/plant, fruit weight, fruit diameter, fruit length, cavity length, cavity diameter and flesh thickness. Different distance level from litchi tree showed the significant effect on the yield and yield contributing parameters of papaya variety due to mostly varing light intensity. In 100% PAR level (Control) produced the highest fruit weight/plant (19.67 kg/plant) followed by 4.5m distance yield (18.44 kg/plant), 3m distance yield (16.25 kg/plant) and the lowest yield was obtained from 1.5m distance (3.97 kg/plant). On the other hand, the interaction effect between variety and different distance level exhibited non-significant effect on most of the yield contributing parameters of papaya and D_1V_1 treatment combination produced the highest yield (20.11 kg/plant) while D_2V_2 produced the lowest yield (3.73 kg/plant) of papaya. As an undestroried crop ginger contribute at 5.08 t/ha yield in the litchi based multilayered Agroforestry system. Therefore, it may be stated that Shahi variety of papaya is better than Rachi and multistoried Agroforestry system is more beneficial than sole production system.

Rahman *et al.* (2008) stated that multistrata Agroforestry system, based on *Litchi chinensis* and widely practised in North Bangladesh to address the common problem of lack of adoption in Agroforestry. Although the financial cost-benefit analysis of Agroforestry systems may show clear-cut profitability, these systems are often hardly adopted by farmers. Net present values and returns to labor of Agroforestry were five times higher than those of alternative (annual) crops, and yet the adoption rate remained very low. Common economic reasoning is that in such cases, adoption is hampered by capacity constraints of the farmers. This is caused by the underlying institutional structures, that are highly unconducive to Agroforestry. They conclude that action for Agroforestry should focus first of all to get supportive institutions (rules and organizations) in place before focusing on trees and projects, if needed at all.

2.6 Performance of potato in Agroforestry systems

Paul *et al.* (2008) also reported that cane yield was enhanced (6-8%) when it was intercropped with potato for the residual effect of applied fertilizer to intercrop. Gross return and gross margin was higher in cane intercropped with potato over sole crop at both the locations.

Dieme and Ourèyesy (2013) stated that the microtuber is considered one of the most effective means of spreading basic materials, as well as transporting and preserving potato germplasm varieties. To define the optimal conditions for the potato microtuber *in vitro* germination of Aida, Atlas and Odessa varieties, the effects of temperature, physiological age and grade (size) were evaluated. The study conducted at three different temperature levels has demonstrated that the most favorable temperature for microtuber germination at a higher and faster germination rate was 25°C, regardless of the variety. In addition, microtubers of large caliber, greater than 4 mm, germinate more quickly, with a higher germination rate, than smaller size ones (less than 4 mm) for all genotypes. For Atlas, Aida and Odessa varieties, a germination rate equal to 86.66%, 70% and 70% respectively, was obtained for microtubers with a caliber superior to 4 mm. Physiological age influences microtuber germination. The mean length of sprouts, reached after a 7 week incubation period, was more marked at multiple sprout and branched sprout" stages than at a "monosprout" stage. The average length was 2.35 cm, 2.48 cm and 1.5 cm, respectively. Thus, it is necessary to plant microtubers at a multiple sproutsta.

Patel *et al.* (2008) observed the tuber yield in potato was affected by genotype /environment relations. In North Gujarat, Kufri Pukhraj established good in wide range of environment, and where as other two varieties were adapted to suitable environment only.

As a main season crop, Kufri Badshah was preferably suitabe for a wide range of environment.

Avasthe *et al.* (2007) observed that nine major Agroforestry systems are in practice in the sub-stropical and mid-hill temperate zones of Sikkim, India. Among them only agri-horticultural (maize- potato) are found to be more viable and economically feasible than other system. The economics revealed that the maize-potato cultivation generated almost Rs. 48 000/- per hectare.

Luthra (2005) showed significantly encouraging relationship of tuber yield with all the character. Plant height, though had low direct effect on tuber yield and their optimistic involvement to tuber yield been largely through average tuber weight and tuber number respectively. Average tuber weight was negatively related with tuber number. Significant difference in total and grade wise tuber yield of potato in potato varieties was noted (Chettri *et al.*, 2005). Kufri Jyoti produced more number of tubers (222.6) than Kufri Chandra Mukhi 215.8. Relationship of size of tubers and number of tubers per plant were influenced by temperature. Higher average tuber yield was in Kufri Chandramukhi (32.5 t/hac.) The cultivars however did not differ for average tuber weight (Singh and Ahmad, 2008).

Malik *et al.* (2005) proposed a model for predicting the changes in growth of industrial Agroforestry plantations under intercropping, weeding and fertilizer practices. The model also enabled the prediction of the growth, growth rate and felling period of *Eucalyptus globulus* under Agroforestry system. The model was applied to growth data of four years pulpwood plantation of *E. globulus* under Agroforestry practices with intercrop of potato (*Solanum tuberosum*), beans (*Phaseolus lunatus*), maize (*Zea mays*) and also with silvicultural practices such as weeding and fertilizer treatments in the long term Agroforestry experiments conducted in Palani Hills, Tamil Nadu, India. Eucalyptus with potato intercrop gave higher yield of pulpwood in all the trials. Eucalyptus has maximum growth at fourth year. Eucalyptus grown with compatible intercrops reached its maximum potential of active growth in 6th year.

In Tamil Nadu, India, Madhu *et al. (*2005) conducted a field experiment to study the effect of lopping on biomass production of *Eucalyptus globulus* and yield of potato and oats in Agroforestry system. Trees which were not lopped up to the 10th year produced the highest total biomass of 436.63 t ha-1 whereas those lopped in alternate years and every year from the 4th year produced 218.29 and 140.76 t ha-1, respectively. The reduction in intercrop yield of potato was 12.4-15.6% in Agroforestry system as compared to sole crop but potato was the most profitable option, and, therefore, recommended for higher production, profitability and protection of sloping lands in the Nilgiri hills.

An experiment was undertaken by Sukhjinder and Dhatiwal (2005) to study the economics of poplar (Populus) cultivation and constraints being faced by the poplar growers in Punjab, India. Three types of Agroforestry systems (AFS) were studied; AFS-I (wheat-kharif fodder), AFS-II (sugarcane for first three years and then wheat-kharif fodder for the successive years) and AFS-III (potato -kharif fodder for first year and then wheat-kharif fodder for the successive years). The highest net present value (NPV) was Rs. 116 068.60 per acre in Ludhiana for AFS-II in 6th year while it was Rs. 126 891.90 per acre for AFS-II in 6th year. However, their profitability could be further enhanced through government intervention and enhanced management of poplar plantation.

Minhas and Kumar (2005) found the average weight of tuber increased as the night temperature decrease in two varieties. Higher day temperature also have affect on tuberization.

Subhash-Chand *et al.* (2002) found that cultivation of potato and scented geranium with eucalyptus is found to be most economical in the Nilgiris area of Tamil Nadu, India. The *Eucalyptus globulus* + potato (Kufri Jyoti) Agroforestry system is found to be more profitable than pure Eucalyptus plantation.

Dagar and Singh (2002) suggested that tuber crops are feasible to grow under partial shade with *Casurina equisitifolia*. Tuber yield (turmeric, potato, taro) was higher under partial shade when the crops were grown during the second year compared with control (without tree) but was reduced markedly under complete shade. During the third year, the turmeric yield increased in partial shade while potato and taro yields declined slightly.

Patel *et al.* (2000) investigated that potato is a weather sensitive crop; its growth and production are obviously affected by environmental conditions. Temperature above 18-20^{o}C tend to increase haulm growth and lower tuber yield

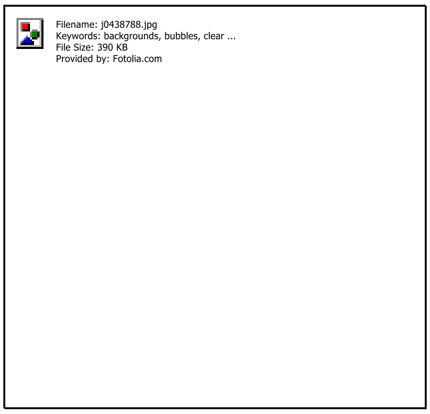
A field experiment was conducted in Gazipur, Bangladesh during winter 1991-92 and 1992-93 by Begum *et al.* (1999) to determine the most productive ratio of maize cv.

Barnali and potato cv. Diamant in an intercropping system. Potato intercropped with 30% maize was the best combination in terms of producing high returns, the highest gross margin (Tk. 44 094), land equivalent ratio and equivalent yield.

Okonkwo (2002) found that the best time to introduce soyabean into potato to obtain maximum production from the intercrop is 20 days after planting potato, when potato is intercropped with soybean.

O'brien *et al.* (1998) carried out over 7 years, examined effects of shading and seed tuber spacing on plant growth, initiation and retention of tubers in four cultivars: Estima, Maris Piper, Maris Peer and Record. Shading by up to 75% did not affect the timing of onset or cessation of tuber initiation in Estima but shading by 50% or more delayed the completion of tuber initiation in Maris Piper compared with less severe shading. Except for intensely shaded treatments (50% or more), the majority of tubers were initiated in a very short period (4–7 days). Shading by 37% or more during the period of tuber initiation and increasing planting density, decreased number of tubers per stem initiated in all experiments, but number of tubers was not affected by shading at other stages of growth. At Cambridge, effects of shading on number of tubers >10 mm retained later in growth from normal planting dates (March to early May) were similar to effects on number of tubers initiated, but effects were much reduced or absent following later plantings at Cambridge and in both experiments in Valencia. The decreased effects of shading on number of tubers >10 mm at late plantings at Cambridge were associated with the initiation of fewer tubers at these plantings. Effects of shading, planting density and planting date on number of tubers were a consequence of changes in the frequency of occurrence and tuberization of different stolon types. Increasing shading and planting density and delaying planting reduced the number of lateral and branch stolons and the frequency of their tuberization but there were no effects on number of primary stolons or their tuberization. Consequently, at Cambridge a similar number of tubers were borne on primary stolons in shaded and unshaded crops. In Valencia a greater proportion of initiated tubers was retained at final harvest from shaded treatments than at Cambridge, which accounts for the absence of effects of shading on number of tubers >10 mm. The greater retention of tubers late in growth in Spain may have been associated with the higher peak growth rates achieved in higher radiation fluxes than at Cambridge.

Agarwal *et al.* (1995) reported that intercropping of black wattle with potato were more economically efficient in the first year of cultivation in Nilgiris in Tamil Nadu than compared to its sole stand but the yield of potato decrease as cultivation goes on.



CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

In this chapter the materials and methods have been presented which include brief description of location of the experimental site, soil, climate, materials used and methods followed in the experiment. The details of these sections are described below:

3.1 Location

The experimental site was selected in the existing litchi orchard of the Agroforestry& Environment Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The geographical location of the site was between 25º 13' latitude and 88º 23' longitude, and about 37.5m above the sea level.

3.2 Soil characteristics

The experimental plot was situated in a medium high land belonging to the old Himalayan Piedmont Plain area (AEZ 01). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The soil P^H was 5.1. The details soil properties are presented in Appendix-I.

3.3 Climate and weather

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (18 November, 2014 to March, 2015)) are included in the Appendix-VII.

3.4 Experimental period

Duration of the experiential period was from November 2014 to March 2015.

3.5 Seed collections

Seed potato tubers were collected from Bangladesh Agricultural Development Corporation (BADC) Domar, Nilphamari.

3.6 Experimental design

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 48. The size of each unit plot was 2m x 2m = 4m^2.

3.7 Experimental treatments

The experiment consisted of 8 (eight) varieties of potato with 2 (two) production systems.

Factor A: (two production systems)

S_1= Litchi + potato,

S_2=Potato on sole cropping

Factor B: (Eight potato variety)

V_1=Diamond,	V_2= Cardinal
V_3= Asterix	V_4= Carage
V_5= Lady Rosette,	V_6= Granula
V_7= Raza,	V_8=4.26 R

Treatments combinations:

S_1V_1= Litchi + Diamond ,	S_1V_2= Litchi + Cardinal
S_1V_3= Litchi+ Asterix	S_1V_4=Litchi + Carage
S_1V_5=Litchi + Lady Rosette,	S_1V_6=Litchi + Granula
S_1V_7= Litchi+ Raza.	S_1V_8= Litchi +4.26 R
S_2V_1= Diamond sole cropping	S_2V_2= Cardinal sole cropping
S_2V_3= Asterix sole cropping	S_2V_4=Carage sole cropping
S_2V_5= Lady Rosette sole cropping	S_2V_6= sole cropping
S_2V_7= Raza sole cropping	S_2V_8=4.26 R sole cropping

3.8 Structural Description

Scientific name: *Litchi chinensis*

Family: Sapindaceae

Variety : China 3

Common name: The litchi has a history and cultivation going back to 2000 BC according to records in China. Cultivation began in the area of southern China, Malaysia, and Vietnam. Litchi is eaten in many different dessert dishes, and is especially popular in China, throughout Southeast Asia, along with South Asia and parts of Southern Africa. It is only known in cultivation, in Malaysia and Indonesia. Litchi are extensively grown in China, and also elsewhere in Brazil, South-East Asia, India, Pakistan, Bangladesh, southern Japan and more recently in California, Jamaica and elsewhere in the Caribbean, Hawaii, Texas, Florida, the wetter areas of eastern Australia and subtropical regions of South Africa, Israel and also in the states of Sinaloa and San Luis Potosí (specifically, in La Huasteca) in Mexico. They are also grown as an ornamental tree as well as for their fruit (Alim and Chowdhury,1962).

Distribution: All tropical and subtropical regions.

Size: Litchi has evergreen long lived tress. *Litchi chinensis* is an evergreen tree that is frequently less than 19 m (62 ft) tall, sometimes reaching more than 15 m (49 ft). The bark is grey-black, the branches a brownish-red. Leaves are 10 to 25 cm (3.9 to 9.8 in) or longer, with leaflets in 2-4 pairs. They are adapted by developing leaves that repel water, and are called laurophyll or lauroid leaves. Flowers grow on a terminal inflorescence with many panicles on the current season's growth. The panicles grow in clusters of ten or more, reaching 10 to 40 cm (3.9 to 15.7 in) or longer, holding hundreds of small white, yellow, or green flowers that are distinctively fragrant. Fruits mature in 80–112 days, depending on climate, location, and cultivar. Fruits vary in shape from round to ovoid to round-shaped. The thin, tough inedible skin is green when immature, ripening to red or pink-red, and is smooth or covered with small sharp protuberances. The skin turns brown and dry when left out after harvesting. The fleshy, edible portion of the fruit is an aril, surrounding one dark brown inedible seed that is 1 to 3.3 cm long and 0.6to 1.2 cm wide (0.39–1.30 by 0.24–0.47 in).

Canopy: Litchi trees typically branch 0.6-2 m (2-6.5 ft) above the ground and develop evergreen, dome-shaped litches grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form.

Roots: The litchi has a long taproot that often branches just below ground level, forming between two and four major anchoring taproots that can reach 6 m (20 ft) down to the water table.

Main uses: Fruit, flavoring, medicinal, timber.

3.9 Land preparation

The land of experimental plot was opened in the first week of November 2014 with a power tiller and it was made ready for planting on 14 November 2014. The corner of the land was spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the field. The layout was done as per experimental design. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil and finally the plots were made ready for planting.

3.10 Application of fertilizers and Manures

Half of urea and full doses of cowdung, TSP, MP, were applied as the basal dose in furrows made on both sides of the seed rows and mixed properly with soil at planting. On the other hand, the remaining urea was applied at 40 DAP during the second earthing-up at the side of the rows and covered with soil.

Fertilizers	Nutrients	Nutrient dose(kg ha^{-1})
Urea	N	135
TSP	P_2O_5	30
MP	K_2O	90
Gypsum	S	10
Zinc Sulfate	Zn	2
Borax	B	1.5
Cowdung		5ton/ha

Source: Fertilizer Recommendation Guide (FRG).2012

3.11 Planting of tubers

The well-sprouted seed tubers were planted on the15th November 2014 at a depth of 10cm in the furrows. The furrows were 60cm apart with the spacing of 25cm in each line.

3.12 Intercultural operations

Weeding and mulching

Manual weeding was done as and when necessary to keep the plots completely free from all weeds. After irrigation, the soil was mulched by breaking the crust for aeration and to conserve soil moisture.

Earthing-up

Earthing-up was made twice during the growing period at 25 days and 40 days after planting. The second one was preceded by top dressing of the remaining half of urea.

Irrigation

Three irrigations were provided throughout the growing period. The first one was done at 30 days after planting. Subsequently two irrigations were given at 20 days interval.

Plant protection measures

Furadan 5G @10 kg/ha was applied during the final land preparation to control ant, mite, cutworm and other soil borne insects. As a preventive measure against late blight Melody Duo 66.8 WP (Iprovelicarb 5.5%, Propineb 61.3%) was sprayed at the rate of 2.5g litre^{-1} water when the weather was cloudy.

3.13 Harvesting

Haulm killing was done before seven days of harvest. The crop was harvested on 24 February 2015 at 100 days after planting when 90% plants showed leaf senescence. At first ten sample plants were harvested from each plot and later on the rest plants were harvested.

3.14 Sampling and data collection

The experimental plots were observed frequently to record various changes in plant characteristics at different stages of their growth. Ten plants were selected at random from each unit plot to collect experimental data. The plants in the outer rows and at the extreme end of the two middle rows were excluded to avoid the border effects. The observations were made on the following parameters during plant growth phase and harvest, which were noted for different treatments of the experiment.

Plant height

The heights were measured from the ground level to the tip of the longest shoot at an interval of 15 days starting from 30, 45, 60 and 75 DAP.

Leaf length

The length of the leaf was obtained with the help of centimeter scale at 30, 45, 60 and 75 DAP.

Leaf breadth

The breadth of the leaf was obtained with the help of centimeter scale at 30, 45, 60 and 75 DAP.

Number of leaves per plant

It was recorded with at an interval of 15 days starting from 30, 45, 60 and 75 DAP.

Number of shoots per hill^{-1}

It was recorded at 30DAP.

Number of tubers hill^{-1}

It was recorded at the time of final harvest. It was recorded as the average of the 10 plants selected at random at harvest from each unit plot.

Weight of tubers hill^{-1}

It was recorded at the time of final harvest.

Yield of tubers

This traitwas recorded from the harvested tubers of all plants of each plot including the sample plants. The yield of tuber plot $^{-1}$ was converted to the yield per hectare.

Dry matter contents (%) of tubers

A sample weight (100g) of freshly harvested tubers was taken and the tubers were cut into small pieces and firstly, air-dried in the laboratory. Air-dried sample was then oven dried for 48 hours at 70^0C± 2 ^{0} C in an oven. After drying it was weighted in an electric balance having a sensitivity of 0.1mg.

Tuber grade

G-A (>55mm) : The middle girth of this grade of tuber was above >55mm

G-B (46-55mm): The middle girth of this grade of tuber was between46-55mm

G-C (36-45mm): The middle girth of this grade of tuber was between 36-45mm

G-D (<36mm): The middle girth of this grade of tuber was between <36mm

3.15 Bio-economics of the potato based Agroforestry system

In order to work out the economic profitability of the Agroforestry systems, the economic yield of the potato and trees was subjected to economic analysis by calculating the cost of cultivation, gross and net returns per hectare and benefit-cost rato. All these parameters were calculated on the basis of market prices prevailing at the time of the termination of experiments.

3.16 Total cost of production

The cost of cultivation of the litchi was worked out on the basis of per hectare. The initial plantation cost of the litchi sapling was included in this study. The management cost of litchi tree was also included. The total cost included the cost items like human labour and mechanical power costs, materials cost (including cost of seeds, fertilizers and manures, pesticide, bamboos, ropes etc.), land use cost and interest on operating capital.

3.17 Gross return

Gross return is the monetary value of total product and by-product. Per hectare gross returns from potato tuber was calculated by multiplying the total amount of production by their respective market prices.

3.18 Net return

Net return usually means the profit of the enterprises. Net return was calculated by deducting the total cost of production from the gross return.

Net return = Gross return (Tk.ha^{-1}) – Total cost of production (Tk.ha^{-1})

3.19 Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculating by using the following formula (Islam *et al.,* 2004)
Benefit-cost ratio = Gross return (Tk.ha^{-1}) / Total cost of production (Tk.ha^{-1})

3.20 Statistical analysis

Data were statistically analyzed using the "Analysis of variance" (ANOVA) technique with the help of computer package MSTAT-C. The mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

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CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results of the performance of eight potato varieties under litchi based Agroforestry system are presented in Table 1 to 13. In this chapter, moreover, the findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield and quality parameters and cost-effective analysis are presented and discussed in this chapter under the following sub-headings to achieve the objective of the study.

4.1 Main effect of variety on growth, yield contributing characters and yield of potato

4.1.1 Plant height

Plant height of potato was recorded from the ground surface to the tip of the leaf in all the treatments. At different Days after Planting (DAP), plant height was found significantly varied with different treatments (Table 1). At 30 DAP, the tallest plant (35.53 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6) whereas the shortest plant (29.19 cm) was observed from Diamond (V_1). Again at 45 DAP, the tallest plant (63.97 cm) was observed from the variety Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Carage (V_4), Asterix (V_3), respectively. On the other hand, the shortest plant height (49.87 cm) was recorded from Diamond (V_1). Similar trend of increasing plant height was observed at 60 DAP, the highest plant height (84.35 cm) was recorded from the variety 4.26 R (V_8) which is significantly followed by the variety of Granula (V_6), Carage (V_4), respectively and the lowest plant height (58.73 cm) was observed from Diamond (V_1). Again at 75 DAP, the highest plant height (91.38 cm) was recorded from the variety 4.26 R (V_8) which is significantly followed by the variety of Granula (V_6), Carage (V_4), Asterix (V_3), respectively. On the other hand, the lowest plant height (67.43 cm)was observed from Diamond (V_1).The result was partially similar with the finding of Garrity *et al.* (1992).

4.1.2 Leaf length

Leaf length of potato was also significantly varied due to different varietal effect (Table 1). At 30 DAP, the longest leaf (17.27 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Carage (V_4), 4.26R(V_8)and Raza (V_7), respectively whereas the shortest leaf (13.03 cm) was observed from Asterix (V_3). Again at 45 DAP, the longest leaf (20.86 cm) was observed from the variety Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Carage (V_4), Raza (V_7),4.26R(V_8), respectively. On the other hand, the shortest leaf (16.19 cm) was recorded from Asterix (V_3). Similar trend of increasing leaf length was observed at 60 DAP and the longest leaf (21.82 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Raza (V_7) and the shortest leaf (16.82 cm) was observed from Asterix (V_3). Again at 75 DAP, the longest leaf (22.08 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Raza (V_7). On the other hand, the shortest leaf (17.45 cm) was observed from Diamond (V_1).This might be attributed due to the situation of cellular expansion and cell division of leaves under shaded condition (Schoch, 1972). Howover, the tread of plant height and leaf length are similar.

4.1.3 Leaf breadth

Potato leaf breadth was also influenced due to their varietal characters (Table 1). At 30 DAP, the widest leaf (10.70 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Carage (V_4), Asterix (V_3), respectively whereas minimum breadth of leaf (9.40 cm) was observed from Diamond (V_1). Again at 45 DAP, the widest leaf (11.87 cm) was observed from the variety Lady Rosette (V_5) which is significantly followed by the variety of Raza (V_7), 4.26R (V_8), Carage (V_4), respectively. On the other hand, minimum breadth of leaf (10.80 cm) was recorded from Diamond (V_1). Again at 60 DAP, leaf breadth was not significantly influenced. The widest leaf (12.45 cm) was recorded from the variety Lady Rosette (V_5) and minimum breadth of leaf (11.68 cm) was observed from Diamond (V_1). Again at 75 DAP, the widest leaf (13.65 cm) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Carage (V_4). On the other hand, minimum breadth of leaf (12.07 cm) was observed from Diamond (V_1). These happened due to varietal characteristics.

Table 1. Main effect of variety on Plant height, Leaf length and Leaf breadth of potato at different DAP

Treatments (variety)	Plant height (cm)				Leaf length (cm)				Leaf breath (cm)			
	30DAP	45DAP	60DAP	75DAP	30DAP	45DAP	60DAP	75DAP	30DAP	45DAP	60DAP	75DAP
Diamond (V_1)	29.19c	49.87c	58.73c	67.43b	13.68b	16.67b	17.05c	17.45c	9.40c	10.80 b	11.68 a	12.07d
Cardinal (V_2)	31.43bc	56.28b	63.30c	73.24b	13.48b	16.41b	16.88c	17.63c	9.76b	11.00 b	12.02 a	12.89bc
Asterix (V_3)	31.41bc	60.44ab	75.29b	82.82a	13.03b	16.19b	16.82c	17.73c	10.12ab	11.13ab	12.38 a	12.52bcd
Carage (V_4)	34.13ab	62.49a	78.48ab	85.99a	15.65a	19.60a	20.11b	20.71b	10.27ab	11.27ab	11.95 a	13.13ab
Lady Rosette (V_5)	35.53a	63.97a	80.65b	85.58a	17.27a	20.86a	21.82a	22.08a	10.70 a	11.87a	12.45 a	13.65a
Granula (V_6)	29.62c	50.38c	60.43c	68.2b	16.02a	19.66a	20.03b	20.26b	9.90bc	10.93 b	11.82 a	12.68bcd
Raza (V_7)	31.05bc	55.09bc	63.64c	72.5b	16.78a	20.40a	20.62ab	21.47ab	9.65bc	11.58ab	12.40 a	12.80bc
4.26 R (V_8)	31.50bc	62.58a	84.35a	91.38a	15.90a	19.17a	19.87b	20.08b	9.71bc	11.28ab	11.97 a	12.23cd
Level of sig.	*	**	**	**	*	*	*	*	*	*	ns	*
CV (%)	8.36	8.23	9.71	9.99	10.65	7.72	5.52	5.62	4.88	5.48	13.25	4.07

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.1.4 Number of leaves shoot^{-1}

Significantly, leaf shoot^{-1} was varied at different DAP among the treatments (Table 2). At 30DAP, Number of leaf shoot^{-1}was not significantly influenced. The maximum number of leaves per shoot (10.12) was recorded from the variety Lady Rosette (V_5) and the minimum number of leaves per shoot (8.86) was observed from Diamond (V_1).At 45 DAP, maximum number of leaves per shoot (15.47) was recorded from the variety Lady Rosette (V_5) whereas minimum number of leaves per shoot (12.33) was observed from Diamond (V_1). Again at 60 DAP, the maximum number of leaves per shoot (17.69) was observed from the variety Lady Rosette (V_5). On the other hand, minimum number of leaves per shoot (13.49) was recorded from Diamond (V_1). Again at 75 DAP, maximum number of leaves per shoot (19.77) was recorded from the variety Lady Rosette (V_5). On the other hand, minimum number of leaves per shoot (14.87) was observed from Diamond (V_1). These happened due to the effect of temperature. Many researchers (Kirk and Marshall, 1992; Delden *et al.*, 2001; Ng and Loomis, 1984;Steward *et al*., 1981) reported that temperature profoundly influences the growth and development of the potato canopy, leaf appearance, expansion, and senescence, leaf orientation and physiological activities of potato plant. The leaf-level photosynthetic rate also varies with temperature; air temperatures at 23°C and above increase the number of auxiliary branches and the leaf appearance and senescence rates (Manrique *et al.,* 1989). This finding was in agreement with the findings of Benoit *et al*., 1986 who stated that, cooler temperatures promote lower number of total leaf and numbers of branches.

4.1.5 Number of shoot hill^{-1}

Shoot hill^{-1} was also significantly inclined by the different varietal effects (Table 2). The maximum number of shoot hill^{-1} (6.26) was recorded from the variety Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Carage (V_4), respectively whereas minimum number of shoot hill^{-1} (3.16) was observed from Diamond (V_1).

Table 2. Main effect of variety on Number of leaves shoot^{-1} and Number of shoot hill^{-1} of potato

Treatments (variety)	No. of leaf per shoot				No. of shoot per hill
	30 DAP	45DAP	60DAP	75DAP	
Diamond (V_1)	8.86a	12.33c	13.49c	14.87e	3.16d
Cardinal (V_2)	9.03a	14.27ab	15.82bc	18.20bcd	3.25d
Asterix (V_3)	9.11a	14.13ab	17.08ab	18.25bcd	5.23ab
Carage (V_4)	9.88a	14.47ab	17.50a	19.00abc	4.06cd
Lady Rosette(V_5)	10.12a	15.47a	17.69a	19.77a	6.26a
Granula (V_6)	9.54aa	14.28ab	16.42b	18.07cd	6.16a
Raza (V_7)	9.81a	13.48bc	16.92ab	17.15d	4.81bc
4.26 R (V_8)	9.40a	14.90ab	17.50a	19.57ab	3.38d
Level of sig.	ns	*	**	**	*
CV (%)	13.73	9.26	6.79	6.25	18.55

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.1.6 Number of tuber hill^{-1}

Tuber hill^{-1} was significantly influenced due to varietal characters (Table 3). The maximum number of tuber hill^{-1} (8.70) was recorded in Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Asterix (V_3), respectively. The minimum number of tuber hill^{-1} (5.35) was found in Diamond (V_1). It was reported that the main growth and yield attributing character responsible for lower yield under poplar were number of tuber and weight of tuber.

4.1.7 Weight of tuber hill^{-1}

Weight of tuber per hill was also influenced by different varieties (Table 3). The maximum weight of tuber (385.61g) was recorded in Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Asterix (V_3), respectively. The maximum weight of tuber hill^{-1} was due the increase in photosynthesis rate resulting in more food materials deposited in tuber. Significantly, minimum weight of tuber (283.10g) was recorded from the variety Diamond (V_1).

4.1.8 Yield (kgPlot^{-1})

The result showed that tuber yield of potato was significantly affected by the different varieties (Table 3). The highest tuber yield plot^{-1}(7.55 kg) was recorded in Lady Rosette (V_5) which is significantly followed by the variety of Granula (V_6), Asterix (V_3), respectively. The lowest tuber yield per plot (4.91 kg) was recorded in Diamond (V_1).

4.1.9 Yield (tha^{-1})

The yield of potato (ton/ha) was significantly affected by the different varieties (Table 3). Significantly the highest tuber yield (18.88 t/ha) was recorded in Lady Rosette (V_5) followed by V_1 (17.67 t/ha), V_3 (17.50 t/ha) and V_7 (14.29 t/ha), respectively. The lowest tuber yield (12.29 t/ha) was recorded in Diamond (V_1).

Table 3. Main effect of variety on yield contributing characters and yield of potato

Treatments (variety)	No. of tuber/hill	Wt. of tuber (gm/hill)	Total wt. of tuber (kg/plot)	Yield (ton/ha)
Diamond (V_1)	5.35c	283.10d	4.91d	12.29d
Cardinal (V_2)	5.58bc	284.00d	5.03cd	12.58cd
Asterix (V_3)	7.48ab	363.36ab	7.00abc	17.50abc
Carage (V_4)	6.76bc	312.70bc	5.85abcd	14.63abcd
Lady Rosette(V_5)	8.70a	385.61a	7.55a	18.88a
Granula (V_6)	7.85ab	365.15ab	7.10ab	17.67ab
Raza (V_7)	6.36bc	301.60bcd	5.71abcd	14.29abcd
4.26 R (V_8)	6.38bc	296.50bcd	5.03cd	13.63bcd
Level of sig.	*	*	*	*
CV (%)	20.86	19.85	25.17	25.13

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.1.10 Percent dry weight of tuber

Percent dry weight of tubers was significantly influenced by the different varieties (Fig. 1). Significantly, the maximum % dry weight (19.90 g) was recorded in potato variety Lady Rosette (V_5) which is significantly followed by Carage (V_4)and 4.26 R (V_8), respectively. On the other hand, the minimum % dry weight (15.35g) of tuber was recorded from Granulla (V_2).

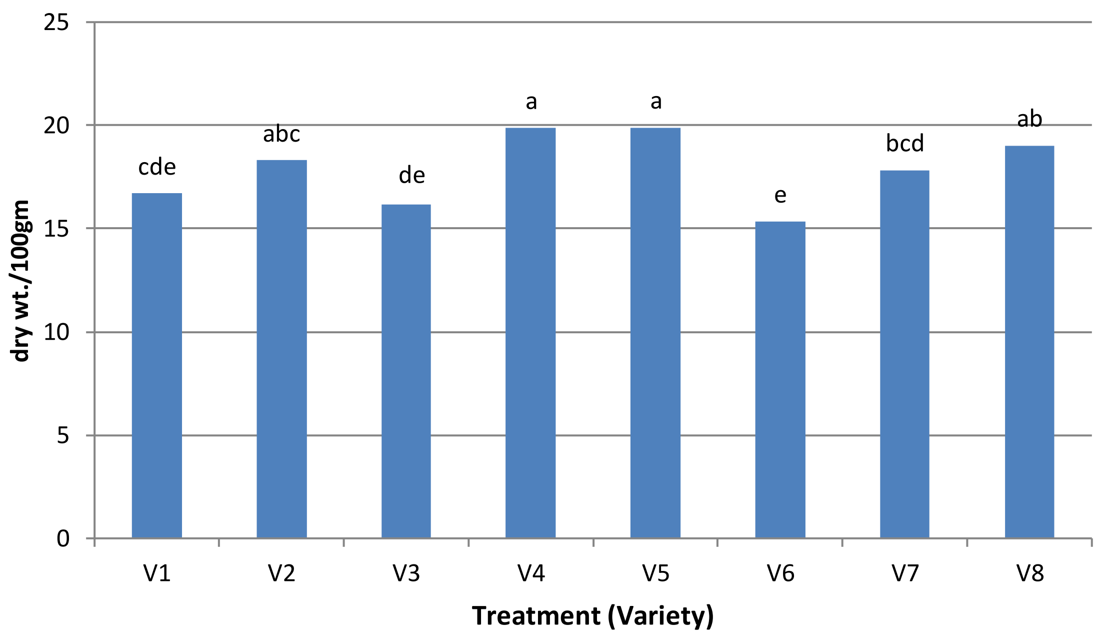

Fig. 1 Main effect of variety on percent dry weight of tuber

4.1.11 Tuber grade hill^{-1}

Grade-A (>55mm)

The grade of tuber was significantly influenced by different varieties (Table 4).The highest (1.76) number of Grade-A tuber (>55mm) was recorded in Lady Rosette (V_5) and the lowest (1.15) number of Grade-A tuber (>55mm) was recorded in the variety of Diamond (V_1).

Grade-B (46-55 mm)

Tuber grade-B (46-55 mm) was not significantly influenced. Numerically the highest (1.41) number of Grade-B tuber was recorded in Lady Rosette (V_5).The lowest (0.96) number of Grade-B tuber was recorded from the variety Diamond (V_1).

Grade-C (36-45 mm)

The tuber grade C (36-45mm) was significantly influenced by different varieties (Table 4). The highest (2.60) number of Grade-C was recorded in Diamond (V_1) and the lowest (1.51) number of Grade-C tuber was recorded in the variety of Lady Rosette (V_5).

Grade-D (<36 mm)

Tuber grade-D (<36 mm**)** was significantly influenced indifferent varieties of potato. the highest (3.35) number of Grade-D tuber was recorded in Diamond (V_1) and the lowest (1.11) number of Grade-D was recorded from the variety Lady Rosette (V_5).

Table 4. Main effect of variety on different size of potato tuber

Treatments (variety)	**Size of tuber no. hill^{-1}**			
	A- grade (>55cm)	**B-grade (46-55cm)**	**C-grade (36-45cm)**	**D-grade (<36cm)**
Diamond (V_1)	1.15 b	0.96 a	2.60 a	3.35 a
Cardinal (V_2)	1.20 b	0.96 a	1.85 ab	2.68 abc
Asterix (V_3)	1.51 a	1.00 a	1.96 ab	2.71 abc
Carage (V_4)	1.66 a	1.31 a	1.78 b	1.51 cd
Lady rosette(V_5)	1.76 a	1.41 a	1.51 b	1.11 d
Granula (V_6)	1.60 a	1.05 a	2.11 ab	2.03 bcd
Raza (V_7)	1.48 a	1.18 a	1.75 b	2.41 bcd
4.26 R (V_8)	1.40 b	1.06 a	1.86 b	2.05 bcd
Level of sig.	*	ns	*	*
CV(%)	23.82	16.33	20.94	32.94

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.2 Main effect of the production system on growth, yield contributing characters and yield of potato.

4.2.1 Plant height

Plant grown under litchi based Agroforestry system was more vigorous than those grown in sole cropping (Table 5). At 30 DAP, the tallest plant (32.53 cm) was observed in litchi+potato based Agroforestry system (S_1) where as the shortest plant was observed (30.92 cm) in sole cropping of potato (S_2). Again at 45 DAP, the tallest plant (58.92 cm) was observed in litchi+potato based Agroforestry system (S_1) where as the shortest plant was observed (56.35 cm) in sole cropping of potato (S_2). Again at 60 DAP, the tallest plant (77.04 cm) was observed in litchi+potato based Agroforestry system (S_1). On the other hand, the shortest plant was observed (64.17 cm) in sole cropping of potato (S_2). Again at 75 DAP, the tallest plant (86.34 cm) was observed in litchi+potato based Agroforestry system (S_1) where as the shortest plant was observed (70.45 cm) in sole cropping of potato (S_2). The present study revealed that the plant height increased with the decrease of light levels. Plant height depends on a number of factors such as availability of required quality of water, mineral nutrients, quantity, quality and duration of light, temperature, area of growing space and genetic set-up of the plants. Hillman (1984) reported that, plant grown in low light levels was found to be more apical dominant than those grown in high light environment resulting in taller plants under shade.

4.2.2 Leaf length

Leaf length of potato was also significant with the production system (Table 5). At 30 DAP, the longest leaf length of potato (16.75 cm) was observed in sole cropping of potato (S_2) where as the shortest leaf length of potato (13.70 cm) was observed in litchi+potato based Agroforestry system (S_1) Again at 45 DAP, the longest leaf length of potato (19.11 cm) was observed in sole cropping of potato (S_2) where as the shortest leaf length of potato (18.12 cm) was observed in litchi+potato based Agroforestry system (S_1). Again at 60 DAP, the longest leaf length of potato (19.47 cm) was observed in sole cropping of potato (S_2) on the other hand, the shortest leaf length of potato (18.82 cm) was observed in litchi+potato based Agroforestry system (S_1). Again at 75 DAP, there is no significant among the production system. However, numerically the longest leaf length of potato (86.34 cm) was observed in sole cropping of potato (S_2) where as the shortest leaf length of potato (70.45 cm) was observed in litchi+potato based Agroforestry system (S_1). This might be attributed due to the situation of cellular expansion and cell division of leaves under shaded condition (Schoch, 1972).

4.2.3 Leaf breadth

Leaf breadth of potato was also influenced by the increase of gloominess i.e. by the production system (Table 5). At 30 DAP, the widest leaf (10.23 cm) was observed in litchi+potato based Agroforestry system (S_1) where as leaf with minimum breadth (9.64 cm) was observed in sole cropping of potato (S_2). Again at 45 DAP, there is no significant among the production system however numerically the widest leaf (11.40 cm) was observed in litchi+potato based Agroforestry system (S_1) where as leaf with minimum breadth(11.07 cm) was observed in sole cropping of potato (S_2). Again at 60 DAP, there is no significant among the production system however numerically the widest leaf (11.90 cm) was observed in litchi+potato based Agroforestry system (S_1). On the other hand, leaf with minimum breadth (11.76 cm) was observed in sole cropping of potato (S_2). Again at 75 DAP, the widest leaf (13.12 cm) was observed in litchi+potato based Agroforestry system (S_1) where as leaf with minimum breadth (12.37 cm) was observed in sole cropping of potato (S_2). It was reported that cooler temperature produce larger size leaves that remain photosynthetically active for longer periods of time.

Table 5. Main effect of production system on Plant height, Leaf Length and Leaf breadth of potato at different DAP

Treatments (production system)	**Plant height (cm)**				**Leaf length (cm)**				**Leaf breath (cm)**			
	30DAP	**45DAP**	**60DAP**	**75DAP**	**30 DAP**	**45DAP**	**60DAP**	**75DAP**	**30 DAP**	**45DAP**	**60DAP**	**75DAP**
Litchi + Potato (S_1)	32.53a	58.92a	77.04a	86.34a	13.70b	18.12b	18.82b	19.65a	10.23a	11.40a	11.90a	13.12a
Potato sole cropping (S_2)	30.92b	56.35b	64.17b	70.45b	16.75a	19.11a	19.47a	19.69a	9.64 b	11.07a	11.76 a	12.37b
Level of sig.	*	*	**	**	**	*	*	ns	*	ns	ns	*
CV(%)	8.36	8.23	9.71	9.99	10.65	7.72	5.52	5.62	4.88	5.48	13.25	4.07

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.2.4 Number of leaves shoot^{-1}

Numbers of leaves per shoot of potato were also significantly disposed by the production system (Table 6). At 30 DAP, there is no significant among the production system however numerically the maximum number of leaves (9.83) was observed in litchi+potato based Agroforestry system (S_1) where as the minimum number of leaves (9.12) was observed in sole cropping of potato (S_2). Again at 45 DAP, the maximum number of leaves (114.35) was observed in litchi+potato based Agroforestry system (S_1) where as the minimum number of leaves (13.98) was observed in sole cropping of potato (S_2). Again at 60 DAP, the maximum number of leaves (17.20) was observed in litchi+potato based Agroforestry system (S_1). On the other hand, the minimum number of leaves(15.51) was observed in sole cropping of potato (S_2). Again at 75 DAP, the maximum number of leaves (19.24) was observed in litchi+potato based Agroforestry system (S_1) where as the minimum number of leaves(16.97) was observed in sole cropping of potato (S_2).The highest number of leaves is due to the effect of temperature pressure. Many researchers (Kirk and Marshall, 1992; van Delden *et al.*, 2001; Ng and Loomis, 1984;Steward *et al.*, 1981) reported that temperature profoundly influences the growth and development of the potato canopy, leaf appearance, expansion, and senescence, leaf orientation and physiological. The leaf-level photosynthetic rate also varies with temperature; air temperatures at 23°C and above increase the number of axillary branches and the leaf appearance and senescence rates (Manrique *et al.*, 1989). This finding was in agreement with the findings of Benoit *et al.*, 1986 who stated that, cooler temperatures promote lower number of total leaf and numbers of branches.

4.2.5 Number of shoots hill^{-1}

Numbers of shoots per plant of potato were not significant among the production system (Table 6). The maximum number of shoots per hill (4.86) was recorded in sole cropping of potato (S_2). However, the minimum number of shoots (4.23) per plant of potato was recorded in litchi+potato based Agroforestry system (S_1).

Table 6. Main effect of production system on Number of leaf shoot^{-1} and Number of shoot hill^{-1} of potato

Treatments (production system)	No. of leaf per shoot				No.of shoot per hill
	30DAP	45DAP	60DAP	75DAP	
Litchi + Potato (S_1)	9.83a	14.35 a	17.20a	19.24a	4.23a
Potato sole cropping (S_2)	9.12a	13.98b	15.51b	16.97b	4.86a
Level of sig.	ns	*	*	**	ns
CV(%)	13.73	9.26	6.79	6.25	18.55

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.2.6 Number of tuber hill^{-1}

Number of tuber hill^{-1} was significantly influenced due to different production system (Table 7). The maximum number of tuber hill^{-1} (7.18) was recorded in sole cropping of potato (S_2). In opposition, the minimum number of tuber hill^{-1} (6.19) was found in Litchi+potato based Agroforestry system (S_1). More sun light gave more photosynthesis produced more carbohydrates accumulated in potato tuber. Corroboratory results from Nandal and Hooda (2005) reported that. The main growth and yield attributing character responsible for lower yield under poplar were number of tuber and weight of tuber.

4.2.7 Weight of tuber hill^{-1}

Weight of tuber per hill was also influenced by the different production system (Table 7). The maximum weight of tuber (384.75 g) was observed insole cropping of potato (S_2)and the minimum weight of tuber (194.87g) was recorded in Litchi+potato based Agroforestry system (S_1).

4.2.8Yield ($kgPlot^{-1}$)

The result showed that tuber yield of potato was significantly affected by the different production system (Table 7). The highest tuber yield per plot (8.77 kg) was recorded in sole cropping of potato (S_2). The lowest tuber yield (3.38 kg) was recorded in Litchi+potato based Agroforestry system (S_1).

4.2.9 Yield (tha^{-1})

The yield of potato (ton/ha) was significantly affected by the different production system (Table 7). The highest yield was found (21.94 ton/ha) in sole cropping of potato (S_2) and the lowest yield (8.43 t/ha) was found in Litchi+potato based Agroforestry system (S_1). The result is in agreement with the findings of Malik *et al.* (2005), the lowest amount of yield was found under kala koroi + Potato based Agroforestry system was due to minimum rate of photosynthesis, which results in lower amount of food materials deposited in the tuber.

Table 7. Main effect of production system on yield contributing characters and yield of potato

Treatments (production system)	No.of tuber/hill	Wt. of tuber(g/hill)	Total wt. of tuber(kg/plot)	Yield(ton/ha)
Litchi + Potato (S_1)	6.19b	194.87b	3.38b	8.43b
Potato sole cropping (S_2)	7.18a	384.75a	8.77a	21.94a
Level of sig.	*	**	**	**
CV(%)	20.86	19.85	25.17	25.13

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.2.10 Percent dry weight of tuber

Percent dry weight of tubers was significantly influenced by the different shade level (Fig. 2). Significantly, the maximum dry weight (19.57 g/100g) was recorded in sole cropping of potato (S_2). However, the minimum dry weight (16.22g/100g) of tuber was recorded in Litchi+potato based Agroforestry system (S_1).

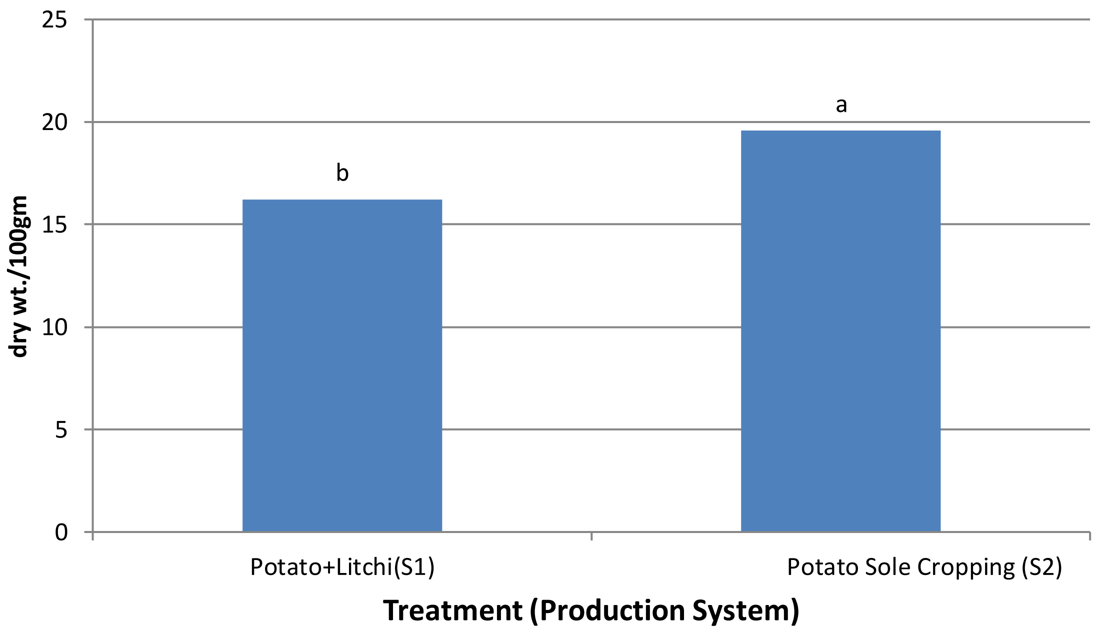

Fig. 2. Main effect of production system on Percent dry weight of tuber

4.2.11Tuber grade hill^{-1}

Grade-A (>55mm)

This grade of tuber was significantly influenced by the different production system (Table 8). The highest number of Grade-A (>55mm) 1.78 was recorded in sole cropping of potato (S_2) and the lowest number of Grade-A (>55mm) tuber 1.29 was recorded in Litchi+potato based Agroforestry system (S_1).

Grade-B (46-55 mm)

The tuber grade-B (46-55 mm) was significant by the different production system (Table 8). The highest number of Grade-B tuber (1.40) was recorded in sole cropping of potato (S_2). The lowest number of Grade-B tuber (0.84) was recorded inLitchi+potato based Agroforestry system (S_1).

Grade-C (36-45 mm)

The tuber grade C (36-45mm) was significantly influenced by the different production system (Table 4.6). The highest (2.16) number of Grade-C was recorded in Litchi+potato based Agroforestry system (S_1) and the lowest (1.75) number of Grade-C tuber was recorded in sole cropping of potato (S_2).

Grade-D (<36 mm)

Tuber grade-B (<36 mm) was significantly influenced by the different production system (Table 8). The highest (2.79) number of Grade-D tuber was recorded in Litchi+potato based Agroforestry system (S_1) and the lowest (2.06) number of Grade-D was recorded in sole cropping of potato (S_2).

Table 8. Main effect of production system on different size of potato tuber

Treatments (production system)	Size of tuber no. hill^{-1}			
	A-grade (>55cm)	B-grade (46-55cm)	C-grade (36-45cm)	D-grade (<36cm)
Litchi + Potato (S_1)	1.29 b	0.84 b	2.16 a	2.79 a
Potato sole cropping (S_2)	1.78 a	1.40 a	1.75 b	2.06 b
Level of sig.	*	*	*	*
CV(%)	23.82	16.33	20.94	32.94

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.3 Interaction effect of variety and production system on the growth, yield contributing characters and yield of potato

4.3.1 Plant height

The interaction effect of variety and production system on the plant height of potato was found significantly different at different days after planting (Table 9). At 30 DAP, the tallest plant of potato (37.27 cm) was recorded in S_1V_5(Litchi + Lady Rosette) which is significantly followed by S_1V_4 (Litchi + Carage). On the other hand, the shortest plant of potato (27.52 cm) was recorded in S_2V_1 (Sole cropping of Diamond). At 45 DAP, the tallest plant of potato (66.77 cm) was recorded in S_1V_5(Litchi + Lady Rosette). On the other hand, the shortest plant of potato (45.88cm) was recorded in S_2V_1 (Sole cropping of Diamond). Significantly at 60 DAP, the tallest plant of potato (91.27 cm) was recorded in S_1V_5 (Litchi + Lady Rosette) which is significantly followed by S_1V_8 (Litchi +4.26 R) and S_1V_4 (Litchi + Carage), respectively. On the other hand, the shortest plant of potato (54.83 cm) was recorded in S_2V_1 (Sole cropping of Diamond). Again at 75 DAP, the tallest plant of potato (97.43 cm) was recorded in S_1V_5 (Litchi + Lady Rosette) which is significantly followed by S_1V_8(Litchi +4.26 R).On the other hand, the shortest plant of potato (61.11 cm) was recorded in S_2V_1 (Sole cropping of Diamond) which were identical with S_2V_6 (sole cropping of Granula) treatments combination, respectively.

4.3.2 Leaf length

Leaf length of potato was significantly different by the interaction effect of variety and production system (Table 9). At 30 DAP, the longest leaf length of potato (18.73 cm) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which is significantly followed by S_1V_7 (Litchi+ Raza). On the other hand, the shortest leaf of potato(10.95cm) was recorded in S_1V_1 (Litchi + Diamond) which followed by S_1V_3 (Litchi + Diamond)and S_1V_2 (Litchi + Cardinal), respectively. Again at 45 DAP, the longest leaf length of potato (21.57 cm) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which is significantly followed by S_2V_7 (Raza sole cropping), S_2V_8(4.26 R sole cropping), S_2V_4 (Carage sole cropping) and S_1V_7 (Litchi+ Raza),respectively. On the other hand, the shortest leaf length of potato (15.32cm) was recorded in S_1V_1 (Litchi + Diamond) followed by S_1V_2(Litchi + Cardinal), S_2V_2(Cardinal sole cropping)and S_2V_3 (Asterix sole cropping), respectively. Again at 60 DAP, the longest leaf length of potato (21.93 cm) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which is significantly followed by S_2V_7(Raza sole cropping), S_2V_8(4.26 R sole cropping) and S_1V_4 (Litchi + Carage),respectively. On the other hand, the shortest leaf of potato (16.43 cm) was recorded in S_1V_1 (Litchi + Diamond) which is followed by S_1V_2 (Litchi + Cardinal), S_2V_2 (Cardinal sole cropping) and S_2V_3 (Asterix sole cropping), respectively. Again at 75 DAP, the longest leaf length of potato (22.13 cm) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which is significantly followed by S_1V_5 (Litchi + Lady Rosette).On the other hand, the shortest leaf of potato (17.27 cm) was recorded in S_2V_2 (Cardinal Sole Cropping) which was identical with S_2V_1(Diamond sole cropping) and S_1V_3(Litchi+ Asterix) treatment combination, respectively.This might be attributed due to the situation of cellular expansion and cell division of leaves under shaded condition (Schoch, 1972).

4.3.3 Leaf breadth

Leaf breadth of potato was also influenced by the variety and the production system (Table 9). At 30 DAP, the widest leaf of potato (11.27 cm) was recorded in S_1 V_5 (Litchi + Lady Rosette). On the other hand, the leaf with minimum breadth (9.20cm) was recorded in S_2V_1 (Diamond Sole Cropping) which is followed by S_2V_7(Raza sole cropping), S_2V_8(4.26 R sole cropping), S_1V_1 (Litchi + Diamond) and S_2V_6(sole cropping Granula),respectively. Again at 45 DAP, the widest leaf of potato (12.33 cm) was recorded in S_1V_5(Litchi + Lady Rosette). On the other hand, the leaf with minimum breadth of potato (10.57cm) was recorded in S_2V_1 (Diamond Sole Cropping). Again at 60 DAP, the widest leaf of potato (21.93 cm) was recorded in S_1V_5 (Litchi + Lady Rosette). On the other hand, the leaf with minimum breadth of potato (16.43 cm) was recorded in S_2V_1 (Diamond Sole Cropping). Again at 75 DAP The widest leaf of potato (14.17 cm) was recorded in S_1V_5(Litchi + Lady Rosette) which is significantly followed by S_1V_4(Litchi + Carage).On the other hand, the leaf with minimum breadth of potato (11.90 cm) was recorded in S_2V_1 (Diamond Sole Cropping) treatment combination. It was reported that cooler temperature produce larger size leaves that remain photosynthetically active for longer periods of time.

Table 9. Interaction effect of variety and production system on Plant height, Leaf length and Leaf breadth of potato at different DAP

Treatments	Plant height (cm)				Leaf length (cm)				Leaf breath (cm)			
	30 DAP	45DAP	60DAP	75DAP	30 DAP	45DAP	60DAP	75DAP	30 DAP	45DAP	60DAP	75DAP
S_1V_1	30.87bcd	53.86cdef	56.28fgh	62.67d	10.95g	15.32f	16.43d	17.27e	9.46cde	11.17abc	11.33ab	12.23de
S_1V_2	32.33abcd	57.37bcde	69.05cdef	80.33bcd	12.58efg	15.98ef	16.63d	17.98cde	9.63bcde	10.90c	12.10ab	13.29abc
S_1V_3	31.35bcd	59.39abcd	82.67ab	85.35bcd	11.37fg	16.58d	17.03d	17.65de	10.37bc	11.20abc	12.50a	12.87bcde
S_1V_4	36.63a	65.38ab	86.29a	92.51ab	14.92cde	19.73ab	20.12abc	20.92ab	10.50ab	11.27abc	11.29ab	13.77ab
S_1V_5	37.27a	66.77a	91.27a	97.43a	15.30bcde	20.15ab	21.70a	22.03a	11.27a	12.33a	12.83a	14.17a
S_1V_6	29.37bcd	51.35def	66.03defgh	74.43cd	14.13def	19.28abcd	19.53bc	19.78bc	10.33bc	11.39abc	12.43a	13.07bcd
S_1V_7	33.10abc	59.58abcd	71.83bcd	83.90abc	15.82abcd	19.77ab	19.97abc	21.53ab	10.10bcde	12.17ab	12.67a	13.10bcd
S_1V_8	32.73abcd	65.66ab	88.03a	95.16a	14.53de	18.21bcde	19.20c	19.47bcd	10.23bcd	11.43abc	12.07ab	12.50cde
S_2V_1	27.52 d	45.88f	54.83h	61.11d	16.00abcd	16.77def	17.07d	17.43e	9.20e	10.57c	10.59c	11.90e
S_2V_2	30.53bcd	55.19cde	57.56efgh	75.53bcd	14.37de	16.83cdef	17.13d	17.87cde	9.90bcde	11.10bc	11.93ab	12.50cde
S_2V_3	31.47bcd	61.48abc	67.92cdefg	73.25cd	15.10cde	17.05cdef	17.20d	17.80cde	9.87bcde	11.07bc	12.27ab	12.17de
S_2V_4	31.00bcd	59.61abcd	70.67bcd	79.48bc	16.38abcd	19.47abc	20.10abc	20.50ab	10.03bcde	11.27abc	12.06ab	12.50cde
S_2V_5	34.43ab	61.17abc	80.67abc	85.33abc	18.73a	21.57a	21.93a	22.13a	10.13bcde	11.00bc	12.07ab	13.13bcd
S_2V_6	29.87bcd	49.42ef	61.18defgh	62.11d	17.90abc	20.03ab	20.53abc	20.73ab	9.47cde	10.87c	11.20ab	12.30cde
S_2V_7	29.00cd	50.61def	55.44gh	72.20cd	18.27ab	21.03a	21.27ab	21.40ab	9.22e	11.40abc	12.13ab	12.50cde
S_2V_8	30.27bcd	59.49abcd	70.03bcde	76.00cd	17.27abcd	20.13ab	20.53abc	20.70ab	9.33de	11.13abc	11.87ab	11.97e
Level of sig.	*	*	*	*	*	*	*	*	*	*	*	*
CV(%)	8.36	8.23	9.71	9.99	10.65	7.72	5.52	5.62	4.88	5.48	13.25	4.07

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.3.4 Number of leaf shoot^{-1}

Numbers of leaves per shoot of potato was also significantly by the variety and the production system at the different day after planting (Table 10). At 30 DAP, the maximum number of leaves (10.63) was recorded in S_1V_5(Litchi + Lady Rosette). On the other hand, minimum number of leaves (8.00) was recorded in S_2V_1 (Diamond Sole Cropping). Again at 45 DAP, the maximum number of leaves (15.80) was recorded in S_1V_5(Litchi + Lady Rosette) which is significantly followed by S_2V_8(4.26 R sole cropping). On the other hand, minimum number of leaves (12.07) was recorded in S_2V_1 (Diamond Sole Cropping). Again at 60 DAP, the maximum number of leaves (19.50) was recorded in S_1V_5 (Litchi + Lady Rosette) which is significantly followed by S_1V_1(Litchi + Diamond). On the other hand, minimum number of leaves (13.00) was recorded in S_2V_1 (Diamond Sole Cropping). Again at 75 DAP, the maximum number of leaves (21.33) was recorded in S_1V_5 (Litchi + Lady Rosette). On the other hand, minimum number of leaves (14.60) was recorded in S_2V_1 (Diamond Sole Cropping). Many researchers (Kirk and Marshall, 1992; van Delden *et al.*, 2001; Ng and Loomis, 1984;Steward *et al.*, 1981) reported that temperature profoundly influences the growth and development of the potato canopy, leaf appearance, expansion, and senescence, leaf orientation and physiological.. The leaf-level photosynthetic rate also varies with temperature; air temperatures at 23°C and above increase the number of axillary branches and the leaf appearance and senescence rates (Manrique *et al.*, 1989). This finding was in agreement with the findings of Benoit *et al*., 1986 who stated that, cooler temperatures promote lower number of total leaf and numbers of branches.

4.3.5 Number of shoot hill^{-1}

Numbers of shoots per hill of potato were significantly inclined by the variety and the production system levels (Table 10). The maximum number of shoots per plant (7.00) was recorded in S_2V_5(Lady Rosette sole cropping) which is significantly followed by S_2V_6(sole cropping Granula) and the minimum number of shoots (2.867) per hill of potato was recorded in S_1V_1 (Litchi + Diamond) treatment combination.

Table 10. Interaction effect of variety and production system on number of leaf shoot^{-1} and number of shoot hill^{-1} of potato

Treatments	No. of leaf per shoot				No. of shoot per hill
	30 DAP	45DAP	60DAP	75DAP	
S_1V_1	10.01ab	13.83abcd	18.10ab	19.80ab	2.87f
S_1V_2	10.37ab	14.60abcd	17.17bcd	19.40ab	2.90f
S_1V_3	9.30ab	13.87abcd	17.83abcd	19.83ab	4.07cdef
S_1V_4	10.10ab	14.20abcd	17.87abc	19.53ab	4.73bcde
S_1V_5	10.63a	15.80a	19.50a	21.33a	5.60abc
S_1V_6	8.47ab	13.60bc	13.83fg	15.13fg	5.53abc
S_1V_7	10.07ab	13.17bcd	15.70def	18.90bc	4.63bcde
S_1V_8	9.67ab	14.33abcd	17.60abcd	20.00ab	3.50def
S_2V_1	8.00b	12.07d	13.00g	14.60g	3.60def
S_2V_2	9.87ab	13.93abcd	14.47efg	17.00cdef	3.27ef
S_2V_3	8.93ab	14.40abcd	16.33bcde	16.67defg	5.73ab
S_2V_4	9.67ab	14.73abc	17.13bcd	18.47bcd	3.47def
S_2V_5	9.07ab	15.14abc	17.40bcd	19.13b	7.00a
S_2V_6	9.27ab	12.60cd	15.73cde	16.33efg	6.73a
S_2V_7	9.00ab	13.80abcd	14.13fg	15.40fg	5.00bcd
S_2V_8	9.13ab	15.47ab	16.87cdef	18.20bcde	4.07cdef
Level of sig.	*	*	*	*	*
CV (%)	13.73	9.26	6.79	6.25	18.55

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.3.6 Number of tuber hill^{-1}

The number of tuber per hill was found significantly different inclined by the variety and the production system (Table 11). The maximum number of tuber (8.93) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which was statistically identical with S_2V_6, S_2V_3, S_2V_2, S_2V_7, S_1V_5 respectively. On the other hand, the minimum number of tuber (4.90) was recorded in S_1V_1 (Litchi + Diamond) which is identical with S_1V_4, S_1V_2,S_1V_6 and S_1V_7 treatment combination.

4.3.7 Weight of tuber hill^{-1}

Tuber per hill was also influenced by the variety and the production system (Table 11). The maximum weight of tuber (406.70 g) was in S_2V_5 (Lady Rosette Sole Cropping) treatment combination. The maximum weight of tuber is due the increase in photosynthesis rate in full sun light condition which results in more food materials deposited in tuber. Significantly, the minimum weight of tuber (190.80 g) was recorded in S_1V_1 (Litchi + Diamond) treatment combination.

4.3.8 Yield (kgplot^{-1})

The result showed that tuber yield (kg/plot) was found significant variation by the variety and the production system (Table 11). The highest tuber yield (10.90 kgplot^{-1}) was recorded in S_2V_5 (Lady Rosette Sole Cropping) treatment combination where as the lowest tuber yield (2.87 kg plot^{-1}) was recorded in S_1V_1 (Litchi + Diamond) treatment combination.

4.3.9 Yield (tha^{-1})

The yield of potato (ton/ha) was significantly affected by the variety and the production system (Table 11). Significantly the highest tuber yield (27.25 t/ha) was recorded in S_2V_5 (Lady Rosette Sole Cropping) treatment combination where as the lowest tuber yield (6.25 t/ha) was recorded in S_1V_1 (Litchi + Diamond) treatment combination.

Table11. Interaction effect of variety and production system on yield contributing characters and yield of potato

Treatments	No. of tuber/hill	Wt. of tuber (g/hill)	Total wt. of tuber (kg/plot)	Yield (ton/ha)
S_1V_1	4.90c	190.80b	2.87e	6.25e
S_1V_2	5.80bc	194.00b	3.13e	7.08e
S_1V_3	6.10bc	197.50b	3.83e	9.58e
S_1V_4	5.10c	204.30b	3.80e	9.33e
S_1V_5	6.93abc	217.00b	4.20de	10.50de
S_1V_6	6.03bc	197.20b	3.87e	9. 67e
S_1V_7	6.00bc	174.50b	2.83e	7.83e
S_1V_8	6.43abc	183.70b	2.48e	7.17e
S_2V_1	6.07bc	368.70a	7.20c	18.00c
S_2V_2	7.07abc	374.00a	6.70cd	16.75cd
S_2V_3	8.33ab	404.30a	10.17ab	25.42ab
S_2V_4	6.47abc	365.00a	7.83bc	21.00abc
S_2V_5	8.93a	406.70a	10.90a	27.25a
S_2V_6	8.47ab	381.30a	10.40ab	26.00ab
S_2V_7	7.60abc	391.30a	8.60abc	21.50abc
S_2V_8	6.73abc	386.70a	8.40abc	19.58bc
Level of sig.	*	*	*	*
CV(%)	20.86	19.85	25.17	25.13

In a column, figures having similar letter(s) do not differ significantly where as figures bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability, ns= Not significant

4.3.10 Percent dry weight of tuber

Percent dry weights of tubers were significantly influenced by the variety and the production system (Fig. 3). Significantly, the maximum dry weight (22.13g) was recorded in S_2V_5 (Lady Rosette Sole Cropping) which is significantly followed by S_2V_4 and S_2V_8 on the other hand, the minimum dry weight (13.73 g) of tuber was recorded under S_1V_6.followed by $S_1V_{3,}S_1V_1$, respectively.

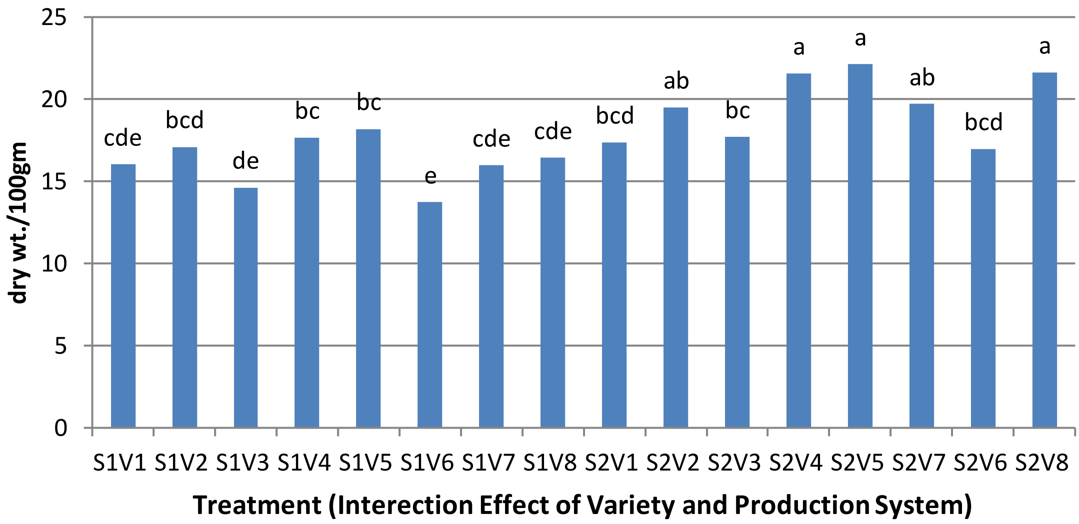

Fig 3. Interaction effect of variety and production on percent dry weight of tuber

4.3.11 Tuber grade hill^{-1}

Grade-A (>55mm)

The grades of tuber were significantly influenced by the variety and the different shade levels (Table 12). The highest (2.00) number of Grade-A (>55mm) was recorded in S_2V_5 (Lady Rosette Sole Cropping) treatment combination. The lowest (1.10) number of Grade-A (>55mm) tuber was recorded in S_1V_1 (Litchi + Diamond) treatment combination.

Grade-B (46-55 mm)

Tuber of Grade-B (46-55 mm) size was significantly influenced by the variety and the different shade levels (Table 12). The highest (1.80) number of Grade-B (46-55 mm) tuber was recorded in S_2V_5 (Lady Rosette Sole Cropping) which was statistically identical S_2V_5, respectively. The lowest (0.33) number of Grade-B (46-55 mm) was recorded in S_1V_1(Litchi + Diamond) treatment combination.

Grade-C (36-45 mm)

Grade-C (36-45 mm) size of tuber was significantly influenced by the variety and the different shade levels (Table 12). The highest (2.83) number of Grade-C (36-45 mm) tuber was recorded in S_2V_5 (Lady Rosette Sole Cropping) that was identical S_1V_1 treatment combination. Apparently, the lowest (1.37) number of Grade-C (36-45 mm) tuber was recorded in S_1V_5 (Litchi + Lady Rosette) treatment combination.

Grade-D (<36mm)

The maximum number of Grade-D (<36mm) potato tuber (4.23) was recorded in S_1V_1 (Litchi + Diamond) treatment combination. Consequently, the lowest (1.00) number of Grade-D (<36mm) tuber was found in S_2V_4

Table 12. Interaction effect of variety and production system on different size of potato tuber

Treatments	Size of tuber no. hill^{-1}			
	A- grade (>55cm)	**B-grade (46-55cm)**	**C-grade (36-45cm)**	**D-grade (<36cm)**
S_1V_1	1.10e	0.33d	2.07abc	4.23a
S_1V_2	1.30cde	0.86bcd	1.83bc	2.30cde
S_1V_3	1.23de	1.03abcd	1.80bc	2.83abcd
S_1V_4	1.33bcde	1.10abcd	1.77bc	1.23cd
S_1V_5	1.46abcde	1.17abc	1.37c	1.97bcd
S_1V_6	1.40bcde	0.90bcd	2.10abc	2.40abcd
S_1V_7	1.27cde	0.80bcd	1.57bc	3.10abc
S_1V_8	1.20de	0.73bcd	1.53bc	3.50ab
S_2V_1	1.73abcd	1.33abc	2.13b	3.47ab
S_2V_2	1.80abc	1.13abc	1.87bc	2.33abcd
S_2V_3	1.60abcde	1.20abc	2.13abc	2.60abcd
S_2V_4	1.87ab	1.53ab	1.80bc	1.00d
S_2V_5	2.00a	1.80a	2.83a	1.07cd
S_2V_6	1.80abc	1.40abc	2.13abc	1.67bcd
S_2V_7	1.87ab	1.13abc	1.47bc	1.73bcd
S_2V_8	1.60abcde	1.67a	2.60ab	2.60abcd
Level of sig.	*	*	*	*
CV (%)	23.82	16.33	20.94	32.94

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing different letter(s) differ significantly(as per DMRT).

* = significant at 5% level of probability

4.4 Economic analysis

Profitability of growing potato as inter-crop in Litchi based Agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of potato and cost of production of tree plantation and management of trees have been summarized in appendix VIII. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 13.

4.4.1 Total cost of production

The values in Table 13.indicate that the total cost of production was maximum (136202 Tk. /ha) in Litchi + potato based Agroforestry system (S_1) whereas the minimum cost of production (130390 Tk./ha) was recorded from the sole cropping of potato (S_2) i.e. potato grown in open field.

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is vary with the variety of potato and production system of potato. The values in Table 13 indicate that the highest value of gross return (476850 Tk. /ha) was obtained from Litchi + potato based Agroforestry system (S_1). On the other hand, the lowest value of gross return (329100Tk. /ha) was obtained from sole cropping of potato (S_2).

4.4.3 Net return

Results presented in the Table 13 show that net return (3406488 Tk./ha) was comparatively higher in producing potato under Litchi + potato based Agroforestry system (S_1). At the same time, the lowest net return (198710Tk. /ha) was received from the sole cropping of potato (S_2).Higher net return was the result of higher gross return from the Litchi + potato based Agroforestry system (S_1).

4.4.4 Benefit-cost ratio (BCR)

The values in Table 13 indicate that the highest benefit-cost ratio (3.50) was recorded from Litchi + potato based Agroforestry system (S_1). On the other hand the lowest benefit-cost ratio (2.52) was observed in sole cropping of potato (S_2). So, potato can profitably be cultivated in Litchi based Agroforestry systems. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 13.Economics analysis of potato production under Litchi based Agroforestry system (ha^{-1}year^{-1})

Production system	Outcome (Tk./ha)		Total cost of Production (Tk./ha)	Gross Return (Tk./ha)	Net Return (Tk./ha))	BCR
	Litchi	potato				
Litchi + Potato (S_1)	350400	126450	136202	476850	340648	3.50
Potato sole cropping(S_2)		329100	130390	329100	198710	2.52

Note: potato 15 Tk. /kg, Litchi tree 8 Year, 400 litchi/tree, 4 Tk. /litchi, Numbers of Litchi tree 219/ha

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CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was carried out at the Agroforestry and environment research farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during November 2014 to March 2015 to evaluate the performance of 8 (eight) potato varieties under litchi based Agroforestry system. The experiment was conducted in newly established Litchi orchard where the tree saplings were planted at the spacing 8 m×8 m in the year 2006. The experiment included eight recommended modern potato varieties viz; V_1=Diamond, V_2= Cardinal, V_3=Asterix, V_4=Carage, V_5= Lady Rosette, V_6= Granula, V_7= Raza, andV_8=4.26 R. The experiment was laid out in RCBD with 3 (three) replications. The treatment combinations of the experiment were S_1V_1=Litchi+ Diamond, S_1V_2=Litchi+ Cardinal , S_1V_3=Litchi+ Asterix, S_1V_4=Litchi+ Carage, S_1V_5=Litchi+ Lady Rosette, S_1V_6=Litchi+ Granula, S_1V_7=Litchi+ Raza, S_1V_8=Litchi+4.26 R, S_2V_1=Diamond sole cropping, S_2V_2= Cardinal sole cropping, S_2V_3=Asterix sole cropping, S_2V_4=Carage sole cropping, S_2V_5=Lady Rosette sole cropping, S_2V_6=sole cropping , S_2V_7=Raza sole cropping and S_2V_8=4.26 R sole cropping. In the treatments, Litchi trees population were 219 trees ha^{-1} respectively

The land of experimental plot was opened in the first week of November 2014 with a power tillar and it was made ready for planting on 14November 2014. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil according to the BARC fertilizer recommendation guide, 2012 and finally the plots were made ready for planting. Potato tubers were planting on 18th November 2014. . Potato tuber was planted as intercrop in the alleys between the two tree rows according to their cultural schedules. The data were recorded on two broad heads, i) growth stage ii) harvesting stage. The data were analyzed statistically and means were adjudged by DMRT (Duncan's Multiple Range Test).

In case of the main effect of variety on the growth, yield contributing characters and yield of potato, the result was found significant in respect of plant height (30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf length(30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf breadth(30 DAP, 45 DAP, 60 DAP and 75 DAP), no. of leaf $shoot^{-1}$ (30 DAP, 45 DAP, 60 DAP and

75 DAP)[1], no. of shoot hill^{-1},no. of tuber hill^{-1} , weight of tuber hill^{-1} , yield plot-1, dry weight (g), tuber grade hill^{-1} respectively. The tallest plant height (35.53 cm,63.97 cm) at 30 DAP, 45 DAP was recorded from the variety of Lady Rosette (V_5) and (84.35 cm, 91.38 cm) at 60 DAP, 75 DAP was recorded from the variety of 4.26R . On the other hand, the shortest plant height (29.19 cm,49.87 cm, 58.73 cm and 67.43 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was observed from the variety of Diamond (V_1). Leaf length of potato was also significantly varied due to different varietals effect. The longest leaf (17.27 cm,20.86 cm, 21.82 cm, 22.08 cm) at 30 DAP, 45 DAP, 60 DAP, 75 DAP was recorded from the variety Lady Rosette (V_5).On the other hand, the shortest leaf (13.03 cm,16.19 cm, 16.82 cm,) at 30 DAP, 45 DAP, 60 DAP, was observed from Asterix (V_3) and 17.45 cm at 75 DAP was observed from Diamond (V_1). Potato leaf breadth was also influenced due to their varietal characters. The widest leaf (10.70 cm,11.87 cm, 13.65 cm) at 30 DAP, 45 DAP, 75 DAP was recorded from the variety Lady Rosette (V_5). On the other hand, minimum breadth of leaf (9.40 cm,10.80 cm, 12.07 cm) at 30 DAP, 45 DAP, 75 DAP was observed from Diamond (V_1). Again at 60 DAP leaf breadth was not significantly influenced. At 30DAP, Number of leaf shoot^{-1}was not significantly influenced. The maximum number of leaves per shoot (15.47,17.69,19.77) at 45 DAP, 60 DAP, 75 DAP was recorded from the variety Lady Rosette (V_5). On the other hand, minimum number of leaves per shoot (12.33,13.49,14.87) at 45 DAP, 60 DAP, 75 DAP was observed from Diamond (V_1). The maximum number of shoot hill^{-1} (6.26) was recorded from the variety Lady Rosette (V_5) and minimum number of shoot hill^{-1} (3.16) was observed from Diamond (V_1).The maximum number of tuber hill^{-1} (8.70) was recorded in Lady Rosette (V_5) and the minimum number of tuber hill^{-1} (5.35) was found in Diamond (V_1). The maximum weight of tuber (385.61g) was recorded in Lady Rosette (V_5) and minimum weight of tuber (283.10g) was recorded from the variety Diamond (V_1). The highest tuber yield per hectare (18.88 t/ha) was recorded in Lady Rosette (V_5) and the lowest tuber yield (12.29 t/ha) was recorded in Diamond (V_1).The maximum percentage dry weight (19.90 g) was recorded in potato variety Lady Rosette (V_5) and the minimum percentage dry weight (15.35g) of tuber was recorded from Granula (V_2). The grade of tuber was significantly influenced by different varieties. The highest number of Grade-A(1.76),Grade-B (1.41) tuber was recorded in Lady Rosette (V_5) and the lowest number of Grade-A (1.15), Grade-B (0.96) tuber was recorded in the variety of Diamond (V_1). However, the suitability of variety will be as Lady Rosette> Granula > Asterix> Carage> Raza> 4.26 R> Cardinal >Diamond.

Again, the result of the research were showed that the main effect of production system were significant in respect of plant height at (30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf length(30 DAP, 45 DAP and 60 DAP), leaf breadth(30 DAP and 75 DAP), leaf shoot^{-} (45 DAP, 60 DAP and 75 DAP)^{1}, ,no. of tuber hill^{-1} , weight of tuber hill^{-1} , yield plot-1, dry weight (g), tuber grade hill^{-1} respectively and the result show not significant in respect of leaf length at 75 DAP, leaf breadth at 45 DAP and 60 DAP, no. of shoot hill^{-1}. The tallest plant (32.53 cm, 58.92 cm, 77.04 cm, 86.34cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was observed in litchi+potato based Agroforestry system (S_1). On the other hand, the shortest plant (30.92 cm, 56.35 cm64.17 cm, 70.45 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was observed in sole cropping of potato (S_2). The longest leaf length of potato (16.75 cm,19.11 cm, 19.47 cm) at 30 DAP, 45 DAP, 60 DAP was observed in sole cropping of potato (S_2). On the other hand, the shortest leaf length of potato (13.70 cm, 18.13 cm, 18.83 cm) at 30 DAP, 45 DAP, 60 DAP was observed in litchi+potato based Agroforestry system (S_1). Again at 75 DAP there is no significant among the production system. The widest leaf (10.24 cm, 13.12 cm) was observed in litchi+potato based Agroforestry system (S_1) where as leaf with minimum breadth (9.64 cm,12.37 cm) at 30 DAP, 75DAP was observed in sole cropping of potato (S_2). Again at 45 DAP and60 DAP there is no significant among the production system for leaf breadth. The maximum number of leaves (114.35, 17.20, 19.24) at 45DAP, 60DAP, 75DAP was observed in litchi+potato based Agroforestry system (S_1) where as the minimum number of leaves (13.98, 15.51, 16.97)at 45DAP, 60DAP, 75DAP was observed in sole cropping of potato (S_2). The maximum number of tuber hill^{-1} (7.18) was recorded in sole cropping of potato (S_2) and the minimum number of tuber hill^{-1} (6.19) was found in Litchi+potato based Agroforestry system (S_1). The maximum weight of tuber per hill (384.75 g) was observed insole cropping of potato (S_2)and the minimum weight of tuber per hill (194.875g) was recorded in Litchi+potato based Agroforestry system (S_1). The highest tuber yield per hectare(21.94 t/ha) was recorded in sole cropping of potato (S_2) and the lowest yield (8.43t/ha) was found in Litchi+potato based Agroforestry system (S_1). Significantly, the maximum dry weight (19.57 g/100g) was recorded in sole cropping of potato (S_2) and the minimum dry weight (16.22g/100g) of tuber was recorded in Litchi+potato based Agroforestry system (S_1). The grade of tuber was significantly influenced by different production system. The highest number of Grade-A (1.78), Grade-B (1.40), was recorded in sole cropping of potato (S_2) and the lowest number of Grade-A (1.29), Grade-B (0.84) tuber was recorded in Litchi+potato based Agroforestry system (S_1).

Again, the interaction effect of variety and production system of potato had significant effect on plant height at (30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf length(30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf breadth(30 DAP, 45 DAP, 60 DAP and 75 DAP), leaf shoot^{-}(30 DAP, 45 DAP, 60 DAP and 75 DAP)^{1}, shoot hill^{-1},no. of tuber hill^{-1} , weight of tuber hill^{-1} , yield plot-1, dry weight (g), tuber grade hill^{-1} respectively. The tallest plant of potato (37.27 cm, 66.77 cm, 91.27 cm, 97.43 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_1V_5 (Litchi + Lady Rosette) .On the other hand, the shortest plant of potato (27.52 cm,45.88cm, 54.83 cm, 61.11 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_2V_1(Diamond sole cropping). The longest leaf length of potato (18.73 cm,21.57 cm, 21.93 cm) at 30 DAP, 45 DAP, 60 DAP was recorded in S_2V_5 (Lady Rosette Sole Cropping). On the other hand, the shortest leaf of potato (10.95cm,15.32cm, 16.43 cm) at 30 DAP, 45 DAP, 60 DAP was recorded in S_1V_1 (Litchi + Diamond). The widest leaf of potato (11.27 cm,12.33 cm, 12.83cm, 14.17 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_1 V_5 (Litchi + Lady Rosette). On the other hand, the leaf with minimum breadth (9.20cm10.57cm, 10.59 cm, 11.90 cm) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_2V_1 (Diamond Sole Cropping). The maximum number of leaves (10.63,15.80,19.50, 21.33) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_1 V_5 (Litchi + Lady Rosette). On the other hand, minimum number of leaves (8.00,12.07,13.00, 14.60) at 30 DAP, 45 DAP, 60 DAP and 75 DAP was recorded in S_2V_1 (Diamond Sole Cropping). The maximum number of shoots per plant (7.00) was recorded in S_2V_5 (Lady Rosette sole cropping) and the minimum number of shoots (2.867) per hill of potato was recorded in S_1V_1 (Litchi+Diamond) treatment combination. The maximum number of tuber (8.933) was recorded in S_2V_5 (Lady Rosette sole cropping) and the minimum number of tuber (4.90) was recorded in S_1V_1 (Litchi+ Diamond). Significantly, the highest tuber yield per hectare (27.25 t/ha) was recorded in S_2V_5 (Lady Rosette Sole Cropping) treatment combination where as the lowest tuber yield per hectare (6.25 t/ha) was recorded in S_1V_1 (Litchi+ Diamond) treatment combination. The maximum dry weight (22.13g) was recorded in S_2V_5 (Lady Rosette Sole Cropping) and the minimum dry weight (13.73 g) of tuber was recorded under S_1V_6. The highest number of Grade-A(2.00), Grade-B(1.80), Grade-C (2.83), was recorded in S_2V_5 (Lady Rosette Sole Cropping) and Grade-D(4.23) potato tuber was recorded in S_1V_1 (Litchi+Diamond) treatment combination. On the other hand, the lowest number of Grade-A (1.10), Grade-B (0.33), was recorded in S_1V_1

(Litchi+Diamond) and Grade-Ctuber was recorded in S_1V_5 (Litchi + Lady Rosette) and the Grade-D (1.00) tuber was found in S_2V_4 treatment combination.

Again, in case of economic analysis, the total cost of production was maximum (136202 Tk./ha) in Litchi + potato based Agroforestry system (S_1) whereas the minimum cost of production (130390 Tk./ha) was recorded from the sole cropping of potato (S_2) i.e. potato grown in open field. The highest values of gross return (476850Tk. /ha) was obtained from Litchi + potato based Agroforestry system (S_1). On the other hand, the lowest value of gross return (329100Tk. /ha) was obtained from sole cropping of potato (S_2). Net return (340648Tk. /ha) was comparatively higher in producing potato under Litchi + potato based Agroforestry system (S_1). At the same time, the lowest net return (198710Tk. /ha) was received from the sole cropping of potato (S_2). The highest benefit-cost ratio (3.50) was recorded from Litchi + potato based Agroforestry system (S_1) and lowest benefit-cost ratio (2.52) was observed in sole cropping of potato (S_2).

5.2 Conclusion

On the basis of the research finding the following conclusion are drown-

1. Growing potato as ground layers crops in litchi tree orchard is a viable option for increasing income of farmers. Despite some negative effects of upper layer tree like Litchi on the growth, yield and physiological attributes of potato, Litchi based Agroforestry system is still beneficial as it ensure higher returns because of diversified products in comparison to sole cropping.

2. It was also pragmatic that potato variety Lady Rosette found to be better in case of yield and more remunerative in comparison to other potato varieties like Granula, Asterix, Carage, Raza, 4.26 R, Cardinal and Diamond under Litchi based Agroforestry systems in this study. The suitability of variety will be as Lady Rosette> Granula > Asterix> Carage> Raza> 4.26 R> Cardinal >Diamond.

3. In open field, the production of potato was higher in comparison to potato + litchi based agroforestry system but it provide two products potato tuber and litchi. It is clear that open field is so good for the production of potato but in avocation of MPTs like Litchi tree it could be grown well.

5.3 Recommendation

1. Potato-Litchi based Agroforestry systems are economically viable under the conditions analyzed. To get highest production of potato, litchi fruit, fuel wood and as well as to bring back equilibrium in the ecosystem, Potato-Litchi based Agroforestry systems are foreseeable.

2. The developed model should be applied in the Litchi and other fruit tree plantation of Bangladesh.

3. The present study opened the avenues for further investigation into the different tree species suitable for Agroforestry system. Moreover, the study revealed that Lady Rosette is good for the tree gardener.

4. This study should be repeated in different location of the country to obtained valid recommendation.

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APPENDICES

APPENDICES

Appendix-I: The physical and chemical properties of soil in Agroforestry& Environment farm HSTU, Dinajpur

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%	30
Clay(%	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
pH	5.35
Organic matter (%)	1.06
Total nitrogen (%)	0.10
Sodium (meq/ 100g)	0.06
Calcium (meq/ 100g)	1.30
Magnesium (meq/ 100g)	0.40
Potassium (meq/ 100g)	0.26
Phosphorus (µg/g)	24.0
Sulphur (µg/g)	3.2
Boron (µg/g)	0.27
Iron (µg/g)	5.30
Zinc (µg/g)	0.90

Source: Soil Resources Development Institute, Dinajpur (2014)

Appendix II. Summary of analysis of variance (mean square) of the plant height, leaf length and leaf breath of potato as influenced by the variety (contd)

Source	Degrees of freedom	Mean square											
		Plant height (cm)				Leaf length (cm)				Leaf breath (cm)			
		30DAP	45 DAP	60 DAP	75 DAP	30 DAP	45DAP	60DAP	75DAP	30DAP	45DAP	60DAP	75DAP
Replication	2	9.866	27.143	227.302	266.093	10.377	13.472	7.483	3.414	0.928	1.501	6.114	0.260
Factor-A	7	27.295*	186.158**	617.157**	498.503**	5.571**	21.519**	22.686**	0.165**	1.005**	0.703*	2.720^{ns}	1.519**
Factor-B	1	31.065*	79.043*	1987.488**	3029.301**	111.752**	11.574*	4.973*	0.020^{ns}	4.260*	1.320^{ns}	0.241^{ns}	6.795*
AB	7	13.069*	44.345*	41.159*	33.080*	1.813*	0.853*	0.438*	0.826*	0.349*	0.580*	2.271*	0.127*
Error	30	7.037	22.481	46.968	61.398	2.629	2.067	1.116	1.222	0.235	0.380	2.460	0.269
CV(%)		8.36	8.23	9.71	9.99	10.65	7.72	5.52	5.62	4.88	5.48	13.25	4.07

Appendix III. Summary of analysis of variance (mean square) of the No. of leaf per shoot and No. of shoot per hill of potato as influenced by the variety and production system

Source	Degrees of freedom	Mean Square				
		No. of leaf per shoot				No. Of shoot per hill
		30 DAP	45DAP	60DAP	75DAP	
Replication	2	2.224	1.113	2.207	0.833	0.439
Factor-A	7	1.198^{ns}	5.300*	13.915**	14.682**	9.683*
Factor-B	1	6.042^{ns}	1.624*	34.307*	61.653**	4.750^{ns}
AB	7	1.134*	0.673*	1.961*	2.345*	0.494*
Error	30	1.692	1.720	1.233	1.280	0.710
CV(%)		13.73	9.26	6.79	6.25	18.55

Appendix IV. Summary of analysis of variance (mean square) of the yield contributing characters and yield of potato as influenced by the variety and production system

Source	Degrees of freedom	Mean square			
		No. of tuber/hill	Wt. of tuber/hill (gm)	Total wt. of tuber/plot (g)	Yield/ha (ton)
Replication	2	2.306	54957.703	24.030	151.189
Factor-A	7	6.617*	635.735*	6.076*	37.559*
Factor-B	1	11.900*	432630.188**	349.650**	2190.376**
AB	7	0.342*	579.616*	2.348*	14.870*
Error	30	1.944	3310.642	2.338	14.561
CV(%)		20.86	19.85	25.17	25.13

Appendix V. Summary of analysis of variance (mean square) of the Size of tuber no.hill^{-1}of potato as influenced by the variety and production system

Source	Degrees of freedom	Mean square			
		Size of tuber no. hill^{-1}			
		A- grade (>55cm)	B-grade (46-55cm)	C-grade (36-45cm)	D-grade (<36cm)
Replication	2	0.948	4.026	15.376	5.535
Factor-A	7	0.064*	0.171^{ns}	0.625*	4.511*
Factor-B	1	2.950*	3.741*	1.960*	6.380*
AB	7	0.032*	0.230*	0.360*	0.205*
Error	30	0.083	0.166	0.366	1.083
CV(%)		23.82	16.33	20.94	32.94

Appendix VI. Interception of light intensity as affected by the upper layer at different dates after planting (DAP) on the top of potato throughout the growing period

Dates of observation	DAP	Treatments		
		Litchi + Potato (S_1)		Open (S_2)
		Light intensity (x100Lx)	% of open	
17.12.14	30	276	64	430
16.01.15	60	240	65	365
15.02.15	90	220	67	328

Appendix VII. Weather data of the experimental site during the period from November 2014 to March 2015

Months	* Air Temperature (^0C)			* Minimum Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
November 2014	29.85	19.68	24.77	05.00	88.50
December 2014	28.70	18.45	23.56	18.00	85.92
January 2015	27.20	16.10	21.65	12.00	83.45
February 2015	26.95	15.78	21.37	00.00	82.20
March 2015	29.61	20.57	25.09	18.50	80.61

Note * Monthly average

Source: Meterological Station, Wheat Research Center, Noshipur, Dinajpur.

Appendix VIII. Cost of production of potato under litchi based Agroforestry system.

Treatments	Input cost										Total input cost (tk/ha)	Over head cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)								Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land (tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
	Litchi Tree	potato	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)					
S_1	9255	24964	31389	32768	9396	3200	2304	5120	12288	65076	99295	7943	24000	4964	136202
S_2	……	37600	37600	49200	14680	5000	3600	…….	…….	72480	110080	8806	6000	5504	130390

Note: S_1=Litchi+potato, S_2=open. Cow dung 600Tk./ton; Urea 20 Tk./kg, TSP 16 Tk./kg; MP 17 Tk./kg, Gypsum 9 Tk/kg, $ZnSO_4$ 40 Tk./kg, Labour 180 Tk./day, Plantation cost for Litchi tree were 30 Tk./tree. Rotation year for Litchi were 60 years

Appendix IX. Some plates of the research

Plate 1a. Land preparation for Potato Tuber Planting

Plate 1b. Potato Tuber Planting

Plate 1c. Potato under litchi orchard at 30 DAP

Plate 1d. Tagging of Potato Plant

Plate 1e. Measurement of Plant Height at 30 DAP

Plate 1f. Measurement of leaf length at 30 DAP

Plate 1g. Measurement of leaf breath at 30 DAP

Plate 1h. Potato plant under open condition

Plate 1i. Potato research field

Plate 1j. Measurement of plant height at 60 DAP

Plate 1k. Cutting the plant haulm before harvesting

Plate 1l. Harvesting the potato tuber

Plate 1m. Different potato variety

Plate 1n. Weighting of 100gm potato tuber for air drying

Plate 1o. Potato tuber taken in laboratory for air drying

Plate 1p. Cutting of potato tuber for air drying

Plate 1q. Slice of tuber for air drying

Plate 1r.Slice of potato for oven drying