

**SCREENING OF CABBAGE VARIETIES INFLUENCED BY  
DIFFERENT FERTILIZER AND MANURE APPLICATIONS  
UNDER MANGO BASED AGROFORESTRY SYSTEM**



**A THESIS  
BY**

**SAL SABIN SARONI  
Registration No: 1605450**

**Session: 2016**

**Thesis Semester: July-December, 2017**

**MASTER OF SCIENCE (M.S.)**

**IN**

**AGROFORESTRY AND ENVIRONMENT**

**DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT**

**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY  
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**DECEMBER 2017**

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*Dedicated to  
My Beloved Parents  
&  
Honorable Teachers*

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## LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
CM	=	Cattle Manure
cm	=	Centimeter
<sup>0</sup> C	=	Degree Centigrade
DAT	=	Days after transplanting
<i>et al.</i>	=	and others ( <i>at elli</i> )
FAO	=	Food and Agriculture Organization
FYM	=	Farm Yard Manure
GA	=	gibberellic acid
IAA	=	indole acetic acid
Kg	=	Kilogram
Kg ha <sup>-1</sup>	=	Kilogram/hectare
LER	=	Land Equivalent Ratio
m	=	Meter
mg	=	miligram (s)
MOC	=	mustard oil cake
MOP	=	Muriate of Potash
PM	=	Poultry Manure
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
TSP	=	Triple Super Phosphate
T ha <sup>-1</sup>	=	ton/hectare
%	=	Percent

# CHAPTER 1

## INTRODUCTION

Cabbage (*Brassica oleracea* L.) is a member of the cole crops and belongs to the family Cruciferae. It is an important fresh and processing vegetable crop in most of the countries of the world. Cole crops are biennials, but are generally grown as annuals. They are suited to the climate of many regions. It is a vegetable crop and generally grown in Rabi season in Bangladesh. Growth and yield of this vegetable crops remarkably influenced by organic and inorganic nutrients management. It is an established fact that use of inorganic fertilizer for the crops is not so good for health because of residual effect but in the case of organic fertilizer such problem does not arise and on the other hand it increase the productivity of soil as well as crop quality and yield (Tindall, 2000). Cabbage is believed to have originated in Western Europe and it was the first cole crop to be cultivated. Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes (Silva, 1986). In addition to the fresh market, cabbage is now processed into Kraut, egg rolls and cole slaws and there is the potential for other specialty markets for the various types including red, savoy and mini cabbage. Cabbage is an excellent source of Vitamin C. In addition to containing some B vitamins, cabbage supplies some potassium and calcium to the diet. 250 mL of raw cabbage contains 21 kilocalories and cooked, 58 kilocalories (Haque, 2006).

The productivity of cabbage per unit area is quite low as compared to the developed countries of the world (Anon., 2006). At present cabbage is cultivated in an area of about 108109.43 ha with total production of 258608 MT cabbage during 2014-2015 in Bangladesh (BBS, 2015).

Mango (*Mangifera indica* L.) is regarded as one of the kings of sub-tropical fruits and it is good source of Vitamin A, B<sub>6</sub>, E, K & C (Slavin, 2012). It contains rich in fiber & prevents night blindness & dry eyes. It decreases risk of cancer. Further research is still ongoing but some studies have already revealed that mangoes are a great natural remedy for diabetics. Mango is cultivated in almost all districts of north-western and south-western region because of soil and weather condition. But now-a-days, mango is cultivated commercially in all districts of Bangladesh. The owners of mango orchard also using the floor of young orchard for different vegetables and spices cultivation. Cabbage

can be successfully cultivated at the floor of young mango orchard. The mango orchard owners are now growing cabbage in their orchard as associated crops. But usually they are using chemical fertilizers and not aware about which variety will give much yield and economic benefits. So, there is a huge scope of production of different variety of cabbage at the floor of mango orchard.

The aims of organic production system are supporting and sustaining healthy ecosystem, soil, farmers, food production, the community and the economy. Reduction and elimination of the adverse effects of synthetic fertilizers and pesticides on human health and the environment is a strong indicator that organic agriculture is gaining worldwide attention. Organic fertilizers are eco-friendly, since they are from organic sources. The current global scenario firmly gives emphasize on the need to adopt eco-friendly agricultural practices for sustainable food production. The cost of inorganic fertilizers is increasing enormously, to the extent that they are out of reach for small and marginal farmers. The organic fertilizers supply nutritional requirements, suppress plant pest populations and increase the yield and quality of agricultural crops in ways similar to inorganic fertilizers. It helps to reduce the use of inorganic fertilizers and contributes in improving soil fertility, soil physical properties and reducing a negative environmental impact. However, some studies have suggested that the excessive use of these agrochemicals may actually increase pest problems in the long run (Altieri and Nicholls 2003). Overall, these results propose a hypothesis that higher synthetic fertilizer inputs may lead to higher levels of herbivore damage to crops (Letourneau, 1996). The excess application of inorganic fertilizer causes hazard to public health and to the environment. But the application of both organic and inorganic fertilizer combinedly, can increase the yield as well as keep the environment sound (Hsieh *et al.*, 1995). Organic fertilizers contain macro-nutrients, essential micro-nutrients, vitamins, growth promoting indole acetic acid (IAA), gibberellic acid (GA) and beneficial microorganisms (Natarjan, 2007). The sustainability of traditional agriculture in Bangladesh is under threat because of the continuous degradation of land and water resources and declining yields due to the indiscriminate use of agro-chemicals. Sustainability in agroecosystems involves environment-friendly techniques based on biological and non-chemical methods (Bonato and Ridray, 2007). So, organic agroforestry production system is very important for Bangladesh. Considering the above circumstances the propose study will be conducted in

order to evaluate organic cabbage production possibility and to find out best cabbage variety under mango based agroforestry system.

Considering the above factors, the present experiment was undertaken with the following objectives:

1. To screen out the suitable cabbage varieties in order to cultivate at the floor of young mango orchard.
2. To find out the effect of mango orchard on organic cabbage production.
3. To find out the economic assessment of organic and inorganic cabbage production under mango based agroforestry system.



## CHAPTER 2

### REVIEW OF LITERATURE

This research has been undertaken to observe the cultivation performance of winter vegetable (cabbage) grown in association with different fertilizers under mango based agroforestry system. The cabbage production through organic and inorganic fertilizer application have been investigated by numerous investigations in various part of the world. In Bangladesh, there has not been much studies investigating the influence either of organic and inorganic fertilizer on cabbage. Relevant information in this connection available in the literature has been reviewed in the following paragraphs with the hope that this may contribute useful information to the present study. Literatures related to this aspects are very limited in our country. The review of literature is the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, periodicals and other form of publications and are presented in this chapter. Under the following sub headings:

2.1 Concepts of Agroforestry

2.2 Benefits of Agroforestry System

2.3 Characteristics of tree species

2.4 Response of crops in Agroforestry System

2.5 Characteristics of Agroforestry System

2.6 Mango based Agroforestry System

2.7 The cabbage plant and its Importance

2.8 Importance of organic production

2.9 Effect of organic manures on cabbage

2.10 Combined effect organic manures and inorganic fertilizers on Cabbage production under Agroforestry System

#### **2.1 Concepts of Agroforestry**

Agroforestry has come of age during the past fifteen years. During this period, activities and interest in agroforestry education and training have increased tremendously, as in other aspects of agroforestry development. Today, agroforestry is taught at the senior undergraduate and postgraduate levels in many institutions around the world, either as a separate subject or as a part of the regular curricula of agriculture, forestry, ecology, and other related programs.

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Agroforestry is recognized as a land use option in which trees provide both products and environmental services. In agroforestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye, 2002).

Agroforestry has both protective and social-economic benefit. Kang (1990) reported that besides direct agricultural benefit, trees exhibit social – economic values. The benefit of the tree components derived by farmers from agroforestry was evaluated from a social economic and ecological perspective (Anderson and Sinclair, 1993).

Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plant (crops, pastures) or livestock, in a spatial arrangement, rotation, or both, there are usually both ecological and economic interactions between the trees and other components of the system.

Agroforestry has been defined as a dynamic, ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996).

The major distinction between agroforestry and these other terms seems to be that agroforestry emphasizes the interactive association between woody perennials (trees and shrubs) and agricultural crops and/or animals for multiple products and services; the other terms refer to tree planting, often as woodlots.

As several authors have pointed out (e.g., Dove, 1992; Laarman and Sedjo, 1992), all these labels directly or indirectly refer to growing and using trees to provide food, fuel, medicines, fodder, building materials, and cash income. Agroforestry is a concept of

integrated land use that combines elements of agriculture and forestry in a sustainable production system. An emphasis on managing rather than reducing complexity promotes a functionally biodiverse system that balances productivity with environmental protection. Agroforestry systems are classified according to the components present – trees with crops are referred to as silvoarable, trees and animals as silvopastoral, and trees with crops and animals as agro-silvopastoral. Agroforestry systems support the production of a wide range of products including food, fuel, fodder and forage, fibre, timber, gums and resins, thatching and hedging materials, gardening materials, medicinal products, craft products, recreation, and ecological services.

## **2.2 Benefits of Agroforestry system**

It should be noted that the attempts being made under agroforestry are to optimize the use of land for agricultural production on a sustainable basis at the same time meeting other needs from forestry (Fagbemi, 2002). Nitrogen-fixing and non-nitrogen-fixing trees thrive adequately in agroforestry with annual crops, presents a farming system in which arable crop yields can be enhanced. The tree rooting system brings about stability that can lead to soil conservation. What is needed would be mutual interaction and proper management techniques that would reduce the adverse effects that may result when trees are integrated into agro-ecosystem (Connor, 1983).

Various authors (Kang *et al.*, 1990; Young, 1986) were of the view that successful agroforestry practices benefits the farmers in the following ways:

### **Agroforestry products**

Agroforestry systems support the production of a wide range of products:

- ❖ Food (arable crops, vegetables, animal products, fruit, mushrooms, oils, nuts, and leaves)
- ❖ Fuel (willow or hazel coppice, charcoal, fuelwood)
- ❖ Fodder and forage
- ❖ Fibre (pulp for paper, rubber, cork, bark and woodchip mulch)
- ❖ Timber (construction and furniture making)
- ❖ Gums and resins
- ❖ Thatching and hedging materials (spars, binders and stakes)
- ❖ Gardening materials (pea sticks, bean poles, fencing, hurdles)

- ❖ Medicinal products (ginseng, goldenseal, witch hazel [ Rao, 2004])
- ❖ Craft products (natural dyes, basketry, floral arrangements)
- ❖ Recreation (agritourism, sport, hunting)
- ❖ Ecological services

### **Agroforestry interactions**

Interactions between the tree and crop/livestock components can be positive, negative or neutral. In the former case complementarity results in increased capture of a limiting resource, and greater total production than if the two components had been grown separately. Conversely, negative interaction, when the two components overlap in their resource use, can lead to competition and hence lower productivity than if the components are grown separately. Where there are no direct interactions between system components, the net effect of combining them is neutral (Jose, 2004).

### **Reducing inputs**

Agroforestry systems are modelled on a natural woodland ecosystem, with the aim of increasing 'eco-efficiency' thereby reducing the need for inputs through minimizing losses and maximizing internal cycling of nutrients. The 'eco-efficiency' of a land-use system is determined by the efficiency and sustainability of resource-use in farm production. It can be improved by achieving a given level of production using fewer resources, with fewer losses to the environment, while maintaining the productive potential of the land and economic performance (Wilkins, 2008). Five keys attributes of eco-efficient farming are (BCPC, 2004):

- ❖ Efficient resource-use with maximum inclusion of renewable resources.
- ❖ No local pollution and no transfer of pollution elsewhere.
- ❖ Predictable output.
- ❖ Functional biodiversity conservation to support ecological processes.
- ❖ Ability to respond promptly to changes in the social, economic and physical environment.

Successful agroforestry systems have the potential to meet all five of the criteria listed above, and by supporting a broader economic base, should maintain or increase farm profitability compared to monoculture systems. Despite the potential for reducing inputs, agroforestry systems in temperate regions are often managed along conventional lines,

however, with inputs of synthetic fertilizers and pesticides. This fails to realize the full potential of agroforestry as a sustainable, low-input system and further research into eco-agroforestry approaches that integrate agroforestry with organic and agro-ecological principles is needed.

### **Environmental benefits of agroforestry**

The role of agroforestry in protecting the environment and providing a number of ecosystem services is promoted as a key benefit of integrating trees into farming systems. As traditionally employed, these benefits were intuitive to the farmers and landowners that managed agroforestry systems, although the scientific evidence to support such benefits is only now coming to light (Jose, 2009; Quinkenstein, 2009 and Borin, 2009) . The impact of agroforestry on the environment occurs at a range of spatial and temporal scales; from fine-scale impacts on soil structure and quality to impacts on the environment and society at regional or global scales.

- **Soil**

Soil management is a key feature of agroforestry systems, and in both tropical and temperate climates, agroforestry systems are designed and implemented to counter soil erosion and degradation, and improve soil quality and health.

- **Water**

The effects of agriculture on water systems are numerous and include changes to water chemistry with eutrophication and food web modifications, pesticide pollution, increased sediment load from soil erosion, changes to hydrological cycles via changes in evapotranspiration rates and run-off, modification of river flow and irrigation impacts, effects of exotic species, and physical modification of the habitat through canalization, drainage and embankment (Moss, 2008). Research has demonstrated that agroforestry can reduce pollution from crops and grazed pastures, with tree strips located adjacent to water courses reducing non-point source water pollution from agricultural land in five key ways:

- ❖ Reducing surface runoff from fields.
- ❖ Filtering surface runoff.
- ❖ Filtering groundwater runoff.
- ❖ Reducing bank erosion.
- ❖ Filtering stream water.

- **Biodiversity**

Agroforestry systems by their very nature are more diverse than monocultures of crops and livestock; this increase in ‘planned’ biodiversity i.e. the components chosen by the farmer, increases the ‘associated’ biodiversity i.e. the wild plants and animals occurring on the farmland. Five main ways that agroforestry contributes to the preservation of biodiversity are (Jose, 2009):

- ❖ By providing habitat for species that can tolerate a certain level of disturbance;
- ❖ By helping to preserve germplasm of sensitive species;
- ❖ By helping to reduce the rates of conversion of natural habitat and alleviate resource use pressure;
- ❖ By providing connectivity through corridors created between habitat remnants and the conservation of area-sensitive floral and faunal species;
- ❖ By helping to conserve biological diversity through providing other ecosystem services
- ❖ Such as erosion control and water recharge, thus preventing habitat degradation and loss.

- **Climate change**

There has been an increase in research over the last 20 years investigating the potential of agroforestry as a tool for addressing the issues of climate change through mitigation and adaptation. Three groups of activities through which forest management can contribute towards reducing atmospheric carbon are (Montagnini, F. and P.K.R. Nair, 2004):

Carbon sequestration through afforestation, reforestation, restoration of degraded lands and improved silvicultural techniques to improve growth rates.

Carbon conservation through conservation of biomass and soil carbon in existing forests, improved harvesting practices to reduce logging impact, improved efficiency of wood processing, fire protection and more effective use of burning in forests and agricultural systems.

Carbon substitution through increased conversion of forest biomass into durable wood products to replace energy-intensive materials, increased use of biofuels and enhanced use of harvesting waste as feedstock for bio-fuel (Montagnini, F. and P.K.R. Nair, 2004).

- **Culture**

Cultural aspects of traditional agroforestry systems, particularly in temperate regions, are often overlooked, despite the long history of woodland and orchard grazing, alpine wooded pastures, pannage, the dehesa and parklands (McAdam, J., *et al.*, 2008). Lifestyles such as nomadism, transhumance (seasonal movement of people with their livestock) and traditional techniques such as pollarding and hedge-laying, are integrated within such systems and the symbolic and cultural perception of these landscapes are shaped by local practices, laws and customs. While only remnants of these traditional landscapes exist today, the significance and value of these cultural landscapes have been recognized at the international level by UNESCO and at the European level by the European Landscape Convention. Within the UK, National Park status was awarded in 2005 to the New Forest, to protect one of the largest remaining areas of wood-pasture in temperate Europe.

### **2.3 Components of Agroforestry System**

#### **Land**

Agroforestry is not a system of pots on a balcony or in a greenhouse. It is a system by which land is managed for the benefit of the landowner, environment and long-term welfare of society. While appropriate for all landholdings, this is especially important in the case of hillside farming where agriculture may lead to rapid loss of soil. If the farmer owns the land, s/he has a vested interest in thinking conservatively, how the land can be maintained over long periods of time. Unfortunately, farmers who rent land may have less interest in the long-term benefits of agroforestry and may even fear that making improvements will raise the rent or result in the lease being terminated.

#### **Trees**

In agroforestry, particular attention is placed on multiple purpose trees or perennial shrubs. The most important of these trees are the legumes because of their ability to fix nitrogen and thus make it available to other plants. The roles of trees on the small farm may include the following:

- ❖ Sources of fruits, nuts, edible leaves, and other food.
- ❖ Sources of construction material, posts, lumber, branches for use as wattle (a fabrication of poles interwoven with slender branches etc.).

- ❖ Sources of non-edible materials including sap, resins, tannins, insecticides, and medicinal compounds.
- ❖ Sources of fuel.
- ❖ Beautification.
- ❖ Shade.
- ❖ Soil conservation, especially on hillsides.
- ❖ Improvement of soil fertility.

In order to plan for the use of trees in agroforestry systems, considerable knowledge of their properties is necessary. Desirable information for each species includes its benefits, adaptability to local conditions (climate, soil, and stresses), the size and form of the canopy and root system, and suitability for various agroforestry practices. Some of the most common uses of trees in agroforestry systems are:

- ❖ Individual trees in home gardens, around houses, paths, and public places.
- ❖ Dispersed trees in cropland and pastures.
- ❖ Rows of trees with crops between (alley cropping).
- ❖ Strips of vegetation along contours or waterways.
- ❖ Living fences and borderlines, boundaries.
- ❖ Windbreaks.
- ❖ Terraces on hills.
- ❖ Small earthworks.
- ❖ Erosion control on hillsides, gullies, channels.
- ❖ Woodlots for the production of fuel and timber.

### **Non-trees**

Any crop plant can be used in agroforestry systems. The choice of crop plants in designing such systems should be based on those crops already produced in a particular region either for marketing, feeding animals, or for home consumption, or that have great promise for production in the region. In keeping with the philosophy of agroforestry, however, other values to be considered in crop selection include proper nutrition, self-sufficiency and soil protection. Thus, selection of crops requires a judgment based on knowledge of the crops, adaptations, production uses, as well as family needs, opportunities for barter, and markets.



## 2.4 Response of crops in Agroforestry System

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

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

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

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

## 2.5 Characteristics of Agroforestry System

- Multiple plant components, at least one of which must be a woody perennial. Components of the system, either ecological and / or economical.
- A high level of interaction (economic and biophysical) between the woody and non-woody components.
- Usually multiple products, often of different categories (e.g. food, fodder, fuelwood).
- The cycle of an agroforestry system is always more than one year.
- The most simple agroforestry system is more complex, ecological and economically than a mono-cropping system.

## 2.6 Mango based Agroforestry System

Agroforestry is an ancient practice and now it is becoming an integral part of the traditional farming systems in Bangladesh. Fuel shortage in our country has led to increasing use of cowdung and agricultural residues causing loss of soil fertility and crop yield. Farmers sometimes grow field crops in and around different types of orchard viz. mango. Mango (*Mangifera indica*) is regarded as one of the kings of sub-tropical fruits and it is good source of Vitamin A, B<sub>6</sub>, E, K & C (Slavin, 2012). It contains rich in fiber & prevents night blindness & dry eyes. It decreases risk of cancer. Further research is still ongoing but some studies have already revealed that mangoes are a great natural remedy for diabetics. Now mango orchards are increasing day by day in the northern part of Bangladesh. The owners of mango orchard also using the floor of young orchard for different vegetables and spices cultivation. Cabbage can be successfully cultivated at the floor of young mango orchard. The mango orchard owners are now growing cabbage in their orchard as associated crops. Thus, the experiment has been undertaken to know the performance of cabbage under mango based agroforestry system.

## 2.7 The cabbage plant and its Importance

Cabbage (*Brassica oleracea* L.) is a member of the cole crops, and it is important fresh, leafy and processing vegetable crop in most of the countries of the world. Cole crops are biennials, but are generally grown as annuals. They are suited to the climate of many regions. Cabbage is a vegetable crop and generally is grown in Rabi season in Bangladesh. Growth and yield of cabbage vegetable is remarkably influenced by organic and inorganic nutrients. Cabbage is believed to have originated in Western Europe and it was the first cole crop to be cultivated. Prior to cultivation and use as food, cabbage was

mainly used for medicinal purposes (Silva 1986). In addition to the fresh market, cabbage is now processed into Kraut, egg rolls and cole slaws and there is the potential for other specialty markets for the various types including red, savoy and mini cabbage. Cabbage is an excellent source of Vitamin C. In addition to containing some B vitamins, cabbage supplies some potassium and calcium to the diet. 250 mL of raw cabbage contains 21 kilocalories and cooked, 58 kilocalories (Haque, 2006).

A rosette of sessile leaves arises as the growing point continues to form leaf primordial. The outer leaves are green in colour and the inner ones are white. As the plant grows, the leaves increase in number, forming a ball-shaped "head" in the centre of the plant. The head is basically a large vegetative terminal bud, formed by overlapping of numerous leaves developing over the growing point of its shortened stem.

Cabbage grows best in a relatively cool and humid climate. Leaves are more distinctly petioled and the quality of the head is impaired in drier atmospheres. The delicate flavour is also lost under these conditions. Yield and quality are poor in summer and it is also difficult to control insect pests. The optimum temperatures for growth and development are from 18 °C to 20 °C. It is fairly resistant to frost and can survive temperatures as low as - 3 °C without damage. Cabbage is also adapted to a wide variety of climatic conditions and can such be grown throughout the year in most regions.

Water requirements vary from 380 to 500 mm per crop, depending on climate and length of growing season. Crop water use increases during the growing period with a peak towards the end of the season.

Cabbage can be grown on a wide range of soils but it thrives on well Cabbage can be grown on a wide range of soils but it thrives on well-drained, moisture-retentive loamy soils well supplied with organic matter. It does not grow well on highly acidic soil. The ideal soil p<sup>H</sup> ranges from 5.5 to 6.5 and it should not be allowed to fall below 4.5. In soils with p<sup>H</sup> above 6.5 the leaves become dark but leaf margins die back. Plants in saline soils are also highly susceptible to blackleg.

### **2.8 Importance of organic farming**

Organic farming is a type of agriculture or farming which avoids the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives.

Organic farming systems rely on crop rotation, crop residues, animal manures, legumes, green manure, off-farm organic wastes and bio-fertilizers, mechanical cultivation, mineral bearing rocks. To maintain soil productivity to supply plant nutrients and biological pest control, controlling weeds, insects and other pests. All kinds of agricultural products can be produced organically, including grains, meat, dairy, eggs, fibres such as cotton, jute, flowers etc. Thus organic farming creates a sustainable lifestyle for generations to come.

Organic farmers build healthy soils by nourishing the living component of the soil, the microbial inhabitants that release, transform, and transfer nutrients. Soil organic matter contributes to good soil structure and water-holding capacity.

Organic farmers feed soil biota and build soil organic matter with cover crops, compost, and biologically based soil amendments. These produce healthy plants that are better able to resist disease and insect predation.

Organic farmers' primary strategy in controlling pests and diseases is prevention through good plant nutrition and management.

Organic farmers use cover crops and sophisticated crop rotations to change the field ecology, effectively disrupting habitat for weeds, insects, and disease organisms. Weeds are controlled through crop rotation, mechanical tillage, and hand-weeding, as well as through cover crops, mulches, flame weeding, and other management methods.

Organic farmers rely on a diverse population of soil organisms, beneficial insects, and birds to keep pests in check. When pest populations get out of balance, growers implement a variety of strategies such as the use of insect predators, mating disruption, traps and barriers.

**Some important benefits for organic farming and organic foods:**

- Organic farming is a science in itself which can be learnt easily by any conventional farmer.
- It has been found that by switching to organic farming, conventional farmer can actually reduce its production cost by over 25% as compared to the cost of conventional

farming. This is eliminate the use of expensive synthetic fertilizers and pesticides, minimizing soil erosion by up to 50% and increasing crop yields up to five-folds.

- A well planned transition strategy may allow conventional farmers to adopt new, more effective organic farming practices easily.
- Organic farms can support substantially higher levels of wildlife especially in low lands and where animals can roam in pastures or graze on grassland. Not only does wildlife benefit, but entire ecosystems and ground water are improved by simply following organic farming methods.
- Organic farming practices not only benefit farmers and consumers; but the dairies can benefit. When dairies feed their cows organic feed and graze them on organic fields, the cows experience better health, less sickness, diseases and ultimately produce better tasting milk for consumers.
- Organic farming promotes healthy soils that are teaming with life and rich in micro nutrients and which can be used for decades to grow crops without getting exhausted.
- Consumers purchasing organically grown foods are tastier. Regardless of minimal price differences, consumers can smell, taste and see the difference in the quality of organically grown food products.
- Organically grown products are free from harmful chemicals, artificial flavors and preservatives that ultimately cost consumers more money than non-organically grown products. You can always taste the difference between organically grown and conventionally grown products.

### **2.9 Effect of organic manures on cabbage**

The organic matter is called the life of the soil. Fertility of a particular soil is determined by the presence of organic matter. The organic matter content of soil varies from 0-5% and it depends on several factors like origin of soil, climatic conditions, vegetation, microbial activities etc. The physical, chemical and biological properties of soil are greatly influenced by organic matter. Although, organic matter content all the essential plant nutrients, but after application of organic manures required time to convert its available form to the plant. That is why the response of crops to organic manures is low. But due to the residual and beneficial effects on soil properties, application of organic manures are encouraged. Some available information about the effects of organic manures on cabbage are reviewed here.

Hsieh (2004) conducted an experiment on conventional farming and partial organic farming and showed that growth and yield of cabbage in the organic treatments were greater than in the control. Poultry manure compost treatment gave the highest weight/plant, head diameter and yield, which was 26.28% higher than that of the control, followed by pig manure compost treatment, which was 18.38% higher.

Little research has been carried out on the agronomic value of compost produced from garden organics for vegetable production. A field experiment was established in Camden, near Sydney, Australia, to (i) evaluate the effect of the compost on vegetable production and soil quality relative to conventional practice, (ii) compare vegetable production under high and low soil P status, and (iii) monitor the changes in soil P concentration under two compost treatments relative to conventional farmers' practice. After three successive crops (broccoli, eggplant and cabbage), results indicate that compost (120 dry t/ha) and half-compost (60 dry t/ha supplemented by inorganic fertilizers) treatments can produce similar yield to the conventional practice of using a mixture of poultry manure and inorganic fertilizer. Furthermore, similar yields were achieved for three different crops grown under high and low P soil conditions, clearly demonstrating that the high extractable soil P concentrations currently found in the vegetable farms of Sydney are not necessary for maintaining productivity. The compost treatments also significantly increased soil organic carbon and soil quality including soil structural stability, exchangeable cations, and soil biological properties. Importantly, the compost treatment was effective in reducing the rate of accumulation of extractable soil P compared with the conventional vegetable farming practice. Our results highlight the potential for using compost produced from source separated garden organics in reversing the trend of soil degradation observed under current vegetable production, without sacrificing yield (Chan *et al.* 2008).

Vimala (2006) conducted an experiment to determine the effects of organic fertilizer (processed poultry manure) on the growth, yield and nutrient content of cabbage in tunnel-shaped structures with plastic roof and netted sides in Serdang, Malaysia. Treatments consisted of varying rates (0, 15, 30, 45 and 60 t/ha) of processed poultry manure. The control treatment was an inorganic fertilizer applied at 2 t/ha. A quadratic yield response to organic fertilizer rates, represented by the equation  $Y=9.832 + 0.636x - 0.008x^2$ , where  $Y$ =yield in t/ha and  $x$ =organic fertilizer in t/ha, was recorded. The

optimum rate of fertilizer was 39.75 t/ha. Yields obtained at this rate was 22.47 t/ha. A quadratic response to fertilizer rates was also obtained for canopy width. A linear response was obtained for head diameter. Organic fertilizer rates had significant effects on the P and K contents of the crop. The N content increased with increasing rates of organic fertilizer, although the increase was significant only for the outer leaves. Organic fertilizer rates did not significantly affect Mg content. Nitrate contents did not differ significantly but were highest in the outer leaves with the application of inorganic fertilizer. All rates of organic fertilizer improved the soil chemical properties compared to inorganic fertilizer. It is concluded that about 40 t/ha of processed poultry manure as the sole source of nutrients can be used for organic cultivation of lowland cabbage grown on clay soils under shelter.

Lathiff and Maraikar (2003) conducted an experiments commencing in the season of 1999/2000, on a reddish brown latosolic soil, at Gannoruwa in the midcountry wet zone of Sri Lanka, to study the performance of different vegetable crops when grown as a monocrop and as mixed crops under an organic farming system. Cattle (CM) and poultry (PM) manure, applied at rates of 20, 30, 40 and 10, 20, 30 t/ha, were the only source of nutrients for the crops. For comparison, a chemical fertilizer treatment, using recommended quantities of NPK, was included in all experiments conducted. In the monocrop experiments, aubergine, cabbage and tomato gave comparable or sometimes higher yields when treated with manure than with NPK. The performance of bush bean [*Phaseolus vulgaris*], on the other hand, was poor when treated with manure than with NPK. In the mixed crop experiments, where the performance of different combinations of bush bean, cabbage, capsicum, carrot and knolkhol [*Brassica oleracea* var. *gongylodes*], were tested, there was no significant yield increase with increasing rates of CM, but there was a significant difference between yields obtained with PM at 10 and 30 t/ha. Changes in soil quality, particularly pH and Olsen P content, were evident after 6 seasons of continuous manure application. The medium rate of manure used in this study seems sufficient to produce satisfactory organic vegetable yields.

The chemical composition of the juice obtained from three cabbage cultivars, i.e. Kamienna Gowa, Decema and Amager, was investigated. Ten enzymatic preparations were used to obtain the juices from these cultivars. In both the fresh material and the obtained juices, the contents of dry substance, total extract, total sugars, total acids,

vitamin C [ascorbic acid], macro- and micro elements, proteins, raw fibre and total ash were determined. The results revealed that chemical composition and juice yield were influenced by the cultivar. The best cultivar was Decema, which was characterized by high dry substance (8.55%), total extract (7.33%), proteins (1.40%), total sugars (3.61%), total ash (0.84%) and vitamin C (36.40 mg) in the raw material. In terms of industrial use, however, Kamienna Gowa was the best cultivar, as it gave significantly higher juice yield (74.1%) and more profitable contents of total extract (6.04%), total acids (0.29 g/100 g), vitamin C (20.53 mg), potassium (1674.46 mg/kg), magnesium (104.44 mg/kg) and calcium (340.69 mg/kg). The addition of enzymatic preparations allowed to obtain juices with increased dietary value (Zalewska and Kalbarczyk 2001).

Chemical and physical analysis, 27-d plant growth assays with carrot (*Daucus carota*) and Chinese cabbage (*Brassica campestris* var. *chinensis*), and 5-d phytotoxicity assays with Chinese cabbage and perennial ryegrass (*Lolium perenne*) were used to investigate the suitability of an aerobically digested poultry slaughter house waste for fertilizer in agriculture and the effect of aerobic post-treatment on the properties of the digested material. The digested material appeared to be rich in nitrogen. In 27-d assays with digested material as nitrogen source, carrots grew almost as well as those fertilized with a commercial mineral fertilizer used as reference, whereas, the growth of Chinese cabbage was inhibited. In further 5-d phytotoxicity assays, the digested material inhibited the germination and root growth of ryegrass and Chinese cabbage, apparently because of organic acids present in it. Aerobic post-treatment of the material reduced its phytotoxicity but, probably due to the volatilization of ammonia, resulted in loss of nitrogen (Salminen 2001).

Jiang, La Na (2005) conducted a field experiment and showed that the yield was increased by 23.67% (1234.5 kg/667 m<sup>2</sup>), quality was improved and NO<sub>3</sub><sup>-</sup> content of autumn cabbage was decreased by using organic compound fertilizer. The N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O removal rates for 1000-kg cabbage was 3.7, 1.07 and 6.0 kg, respectively. The N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O ratio was 1:0.29:1.60. The maximum nutrient absorption rate was recorded at 60-80 days after sowing.

Lu, N. and Edwards, J.H. (1994) conducted a greenhouse pot study with a Wynnville sandy loam surface soil to determine the influence of application rates of poultry litter (PL) on growth and nutrient uptake of collard [kale] cv. Champion, and the residual



effects of PL on growth and nutrient uptake of cabbage cv. Rio Verde. PL at 0, 13, 26, 53 and 106 g/kg was incorporated into limed ( $p^H$  6.5) and non-limed ( $p^H$  5.2) soil. Collard plants were grown for 52 days. The residual effects of PL were evaluated by growing 3 successive crops of cabbage without further application of PL (total 218 days). Collard plants were severely damaged or killed within 7 days after transplanting when the application rate of PL exceeded 26 g/kg soil. The rate of PL application that resulted in maximum cabbage DM yield increased from 26 to 106 g PL/kg soil during 3 successive crops. After 4 successive growth periods, 6-37% of N, 3-62% of Ca, 20-120% of K, 5-60% of Mg and 3-25% of P added through PL was removed by plants. The decrease in water-extractable K accounted for the decrease in soil salinity. The results suggest that application rates of PL of  $\leq 53$  g/kg soil can result in elevated levels of salts and  $NH_3$  in soil, which can produce severe salt stress and seedling injury.

Subhan (1988) carried out an experiment on cabbage cv. Gloria Osená and applied 15, 20, 25 or 30 t/ha of cattle manure, composted maize straw or composted rice straw. He observed that application of organic manure increased head diameter at 60 days after planting and the average number of leaves/plant and reduced the number of days to crop maturity. Application of 25 or 30 t cattle manure/ha gave the largest cabbage and the highest yield/plot.

Hochmuth *et al.* (1993) conducted an experiment to investigate the response of cabbage yields, head quality and leaf nutrient status to poultry manure fertilization. They reported that the marketable yield of cabbage responded quadratically to increasing rates of poultry manure during 1990, with the maximum yield (28.4 t/ha) being obtained by 18.8 t/ha. Yields recorded with 1.0 to 1.4 of conventional NPK fertilizer/ha were same as those with the highest rate of manure. The results showed that manuring efficiency was initially higher with commercial fertilizer than the poultry manure alone, since lower amounts of total nutrients were applied using commercial fertilizer.

Beresniewiez and Nowosielski (1985) found that organic fertilization and liming increased total and marketable yield of cabbage at the optimum level of mineral fertilization.

The growth of cabbage in loamy soils was severely inhibited and the yield of marketable head was reduced, as reported by Nishimune *et al.* (1994). They also found that repeated

applications of compost alleviated the problem but yields were not higher compared to newly cropped or rotated fields.

Omori *et al.* (1972) reported that application of 10 t/acre of fresh cattle manure increased the yield of pimento, eggplant and Chinese cabbage but reduced the yield of cucumber and tomato compared with normal (rate unspecified) application. Fresh chicken manure at the rate of 5-10 t/acre could be used for pimento, eggplant and Chinese cabbage without deleterious effect.

Maslo and Gamayunov (1989) conducted an experiment on four-course rotations (Cucumber, tomato, cabbage and potato). They added 65 t/ha cattle manure per rotation, including 40 t/ha for cucumber and 25 t/ha for cabbage. Lime was applied once per rotation, mineral fertilizers were applied at N-308, P-150 and K-390, equivalent to and combined with 65 t/ha FYM or alone at N-330, P-390, K390. The most positive effect on soil fertility was observed following combined mineral and organic fertilizer application. Yield was increased by 57-136% and productivity by 11-33% more than manuring alone.

Cheung and Wong (1983) carried out an experiment on animal manures and sewage sludges for growing vegetables and stated that chicken manure and pig manure resulted in better growth than sewage sludges.

Krupkin *et al.* (1994) made an investigation using poultry manure, mixture of poultry manure plus hydrolysis lignin, and a compost of poultry manure plus hydrolysis lignin as organic fertilizers for potatoes, carrots, cabbage etc. with and without irrigation. The results showed that these organic fertilizers improved the yield and quality of the crop, especially on soil having a low content of nitrate N, but had only little effect on soils well supplied with nitrate N. The lignin based fertilizers i.e. mixture of poultry manure and hydrolysis lignin and a compost of poultry manure plus hydrolysis lignin were similar in their effect to poultry manure.

Flynn *et al.* (1995) carried out an experiment to evaluate the suitability of composted broiler chicken manure as a potting substrate using lettuce plants. They mentioned that the broiler manure containing peanut hulls as bedding material was composted and then combined with a commercially available potting substrate. Highest fresh weight yield was obtained when broiler chicken litter compost was mixed with commercially

available potting substrate at 3:1 ratio. There was no evidence of physiological disorders resulting from excessive nutrient concentrations.

Lu and Edwards (1994) suggested that application of 26 to 106 g Pm/kg soil resulted the maximum DM yield in cabbage grown in a greenhouse pot study in USA.

Roe (1998) carried out an experiment by using compost, obtained from dairy manure and municipal solid waste to find out the beneficial effects on broccoli. He found beneficial effects on growth, yields and nutrient contents with compost application in the broccoli production.

Vidigal *et al.* (1997) performed an experiment in Brazil with lettuce using various organic compounds viz. crushed sugarcane, napier grass and coffee straw mixed with pig slurry in various combinations with or without gypsum or triple superphosphate.

They found that napier grass + coffee straw + pig slurry was the best mixture, increasing yields by 10.8% and 17.6% than those produced by NPK in first and second crops, respectively.

An experiment was carried out by Zarate *et al.* (1997) in Brazil to evaluate the rates and methods of application of poultry manures on lettuce. The soil was supplied with 0, 7 or 14 t semi-rotted poultry manure incorporated into the soil and 0, 7 or 14 t semi-rotted poultry manure applied to the soil surface. They found in the absence on incorporated manure, surface application of 14 t manure/ha gave significantly higher yield (17.8 t fresh matter/ha) than other nutrients. When 7 t/ha was incorporated, the rate of surface application had no significant effect on yields (13.3 - 17 t/ha), whereas when 14 t/ha was incorporated, surface application of 7 t/ha manure gave the significantly highest yields (20 t/ha Fresh matter).

Devliegher and Rooster (1997a) conducted an experiment on lettuce and Chinese cabbage by using pre-plant compost, obtained from different sources. The composts were comprised of (i) GFT, derived from vegetable, fruit and small garden waste; (ii) Humolex, derived from GFT compost, and (iii) green compost, derived from vegetable waste. They applied the composts at 25 t dry matter/ha. They found that average plant weight was increased by GFT and Humolex but green compost had no effect.

Devliegher and Rooster (1997b) carried out another experiment in Belgium on cauliflower, using standard peat-based compost alone or supplemented with green

compost or a GFT- compost. They observed that plant growth was the greatest for plants raised in standard compost and harvest date was earlier.

Alam (2000) conducted an experiment to study the effect of different forms of mustard oil cake (MOC) and its different methods of application with growth and yield of potato (cv. Diamant). He reported that higher yield of tuber (33.31t/ha) was obtained from decomposed form of MOC than powder form (32.18 t/ha).

Yu-Tzu Hsu (2009) conducted an experiment. The objective of this study was to assess the effect of fertilization (organic or synthetic) and cabbage, *Brassica oleracea* L., cultivars on the chemistry of cabbage and on the responses of a cabbage specialist *Pieris rapae crucivora* Boisduval. Cabbages were grown from seeds in the greenhouse with either organic, synthetic, or no fertilizer treatments. Trials of ovipositional preference and larval feeding were conducted to evaluate the effect of foliage quality on insect responses. In addition, the foliar chemistry (water, nitrogen, total nonstructural carbohydrates, sinigrin, and anthocyanin) was measured during the insect bioassays. The results indicated that butterflies preferred to lay eggs on foliage of fertilized plants. The larvae grew faster on plants fertilized with synthetic fertilizer, but there was no evidence that contents of sinigrin delayed the developmental time of the larvae. However, plants that received organic fertilizer had higher biomass. In summary, the results of this study suggested that proper organic treatment can increase a plants biomass production and may have a lower pest occurrence.

Souza *et al.* (2008) indicated that nutrient deficiency and higher rate of nutrient release for crop growth and yield both are less efficient for growth and yield of crop production. An experiment was conducted by them to evaluate the effect of organic and chemical fertilizer on characteristics of cabbage growth (plant height, leaf number, leaf size, stem length and root length) and yield (thickness of head, head diameter and weight of head). The first factor consisted of doses of organic compost: 0, 5, 10, 15 and 20 t/ha and the second factor consisted of mineral fertilizers: 50, 100 and 150 kg/ha of mixed fertilizers. Experiment showed that 15 and 20 t/ha organic compost with 100 kg/ha mixed fertilizer gained best results of plant height, leaf number and size, stem length, thickness, diameter and weight of head. The protein, phosphorus, potassium and magnesium contents in cabbage cultivar increased with the increased doses of organic compost.

Pankaj (2006) conducted a field experiment during the 2003/04 and 2004/05 kharif seasons in Varanasi, Uttar Pradesh, India, to study the integrated effect of bioinoculants (Azotobacter and phosphorus solubilizing microorganisms (PSM), organic fertilizer (farmyard manure and digested sludge) and inorganic fertilizers (NPK), alone and in combination, on the growth and yield of cabbage seedlings. Data were recorded for plant height, stem length, number of primary roots, number of wrapper leaves, number of non-wrapper leaves, weight of non-wrapper leaves, head length, head diameter, fresh weight of head, weight per plant and head yield. The results are presented. Data represented that Azotobacter + farmyard manure + NPK and phosphorus solubilizing microorganisms + digested sludge + NPK were more effective than Azotobacter + farmyard manure, phosphorus solubilizing microorganisms + digested sludge, Azotobacter + digested sludge, phosphorus solubilizing microorganisms + farmyard manure in case of growth (plant height, stem length, number of primary roots, number of wrapper leaves, number of non-wrapper leaves, weight of non-wrapper leaves) and yield (head length, head diameter, fresh weight of head, total weight/plant and head yield) contributing characters of cabbage.

The effects of organic-inorganic compound fertilizers and inorganic nitrogen fertilizers on the quality and yields of Chinese cabbage cv. Luxing Studied by Zhang (2004). The results show that application of organic-inorganic compound fertilizer I produced the highest yield among all treatments; the yield was higher by 14.4, 6.3, 10.6, 4.6 and 33.6% compared with the treatments of ammonium nitrate, ammonium sulfate, urea, organic-inorganic compound fertilizer II and the control, respectively. Among the three inorganic nitrogen fertilizers, the treatment of ammonium sulfate resulted in the highest yield. No significant difference in nitrate content of Chinese cabbage was observed between the treatments with nitrogen fertilizers of different N forms ( $P > 0.05$ ). Of all the nitrogen fertilizers of different N forms, organic-inorganic compound fertilizer I was absorbed by Chinese cabbage cv. Luxing at the highest apparent utilization rate of 29.7% (Zhang, 2004).

### **2.10 Combined effect organic manures and inorganic fertilizers on Cabbage production under Agroforestry System**

Organic manures are the main source of soil organic matter, which has a fundamental effect on the physical and physico-chemical properties of soil. Organic manures also an

important source of plant nutrients but contains relatively small amount, which are not readily available. On the other hand inorganic fertilizer contains specific, higher and readily available plant nutrients. So, the combination of organic manures and inorganic fertilizers must be more productive under agroforestry system. A number of researchers have been conducted to investigate the combined effect of organic manures and inorganic fertilizers on cabbage production under agroforestry system. Some of these research information are reviewed here.

Yu-Tzu Hsu (2009) conducted an experiment. The objective of this study was to assess the effect of fertilization (organic or synthetic) and cabbage, *Brassica oleracea* L., cultivars on the chemistry of cabbage and on the responses of a cabbage specialist *Pieris rapae crucivora* Boisduval. Cabbages were grown from seeds in the greenhouse with either organic, synthetic, or no fertilizer treatments. Trials of ovipositional preference and larval feeding were conducted to evaluate the effect of foliage quality on insect responses. In addition, the foliar chemistry (water, nitrogen, total nonstructural carbohydrates, sinigrin, and anthocyanin) was measured during the insect bioassays. The results indicated that butterflies preferred to lay eggs on foliage of fertilized plants. The larvae grew faster on plants fertilized with synthetic fertilizer, but there was no evidence that contents of sinigrin delayed the developmental time of the larvae. However, plants that received organic fertilizer had higher biomass. In summary, the results of this study suggested that proper organic treatment can increase a plants biomass production and may have a lower pest occurrence.

Bimova (2008) stated that in recent years, the agri-food sector and consumers have begun to look at food not only for basic nutrition, but also for health benefits. The purpose of this study was to investigate the variations in the total antioxidant capacity (TAC) in head cabbage according to the used type of fertilizer. Commercial brands of alternative, organic fertilizers were compared with conventional, mineral fertilizers in culture of head cabbage. There were seven different treatments: Agormin, Agro, farmyard manure, horticultural compost, Dvorecky agroferm, mineral fertilizer, and an unfertilized control. All the treatments assured approximately the same level of nutrients. The level of TAC was measured by the FRAP assay and the effect of storage on TAC was also studied. Average value of TAC in fresh cabbage was  $236 \pm 60$  mg GA/100 g in the year 2005 and  $295 \pm 27$  mg GA/100 g in the year 2006. The TAC value decreased in

the course of storage. The average value of TAC after a five-month period of storage was  $56 \pm 18$  mg GA/100 g in the year 2005 and  $33 \pm 5$  mg GA/100 g in the year 2006. This study shows that alternative, organic fertilizers have similar or even better qualities than farmyard manure and that they can contribute to the improvement of nutritional values of vegetable.

Souza *et al.* (2008) indicated that nutrient deficiency and higher rate of nutrient release for crop growth and yield both are less efficient for growth and yield of crop production. An experiment was conducted by them to evaluate the effect of organic and chemical fertilizer on characteristics of cabbage growth (plant height, leaf number, leaf size, stem length and root length) and yield (thickness of head, head diameter and weight of head). The first factor consisted of doses of organic compost: 0, 5, 10, 15 and 20 t/ha and the second factor consisted of mineral fertilizers: 50, 100 and 150 kg/ha of mixed fertilizers. Experiment showed that 15 and 20 t/ha organic compost with 100 kg/ha mixed fertilizer gained best results of plant height, leaf number and size, stem length, thickness, diameter and weight of head. The protein, phosphorus, potassium and magnesium contents in cabbage cultivar increased with the increased doses of organic compost.

Experiments were carried out in Iran to determine the effects of organic and fertilizer amendments on severity of *M. javanica* in cucumber cv. PS. The treatments were undecomposed farmyard manure (10 t/ha) poultry manure (40 t/ha), green manure i.e. cabbage leaf waste (40 t/ha), compost (40 t/ha), and chemical fertilizers including urea (500 Kg/ha), ammonium phosphate (500 Kg/ha), and potassium sulfate (500 Kg/ha) which were used alone and/or in combination with the organic amendments. The combination of poultry manure and chemical fertilizers (NPK) resulted in greatest reduction of number of eggs and juveniles in soil and roots of cucumber and also of few other tylenchids: *Tylenchus*, *Paratylenchus*, *Psilenchus* and *Helicotylenchus*. Whereas the population of saprophytic nematodes viz. aphelenchids, rhabditids, diplogasterids and cephalobids was increased. The growth of cucumber plants was also highest under this treatment compared with the other treatments. The treatments of poultry manure, combinations of farm yard manure, waste cabbage leaf with chemical fertilizers and farm yard manure were the next effective ones in reduction of egg and juvenile numbers of *M. javanica*, respectively. Cabbage leaf waste, compost and the chemical fertilizer treatments were the least effective treatments (Nasr and Ahmadi, 2005).

Pankaj (2006) conducted a field experiment during the 2003/04 and 2004/05 kharif seasons in Varanasi, Uttar Pradesh, India, to study the integrated effect of bioinoculants (Azotobacter and phosphorus solubilizing microorganisms (PSM)), organic fertilizer (farmyard manure and digested sludge) and inorganic fertilizers (NPK), alone and in combination, on the growth and yield of cabbage seedlings. Data were recorded for plant height, stem length, number of primary roots, number of wrapper leaves, number of non-wrapper leaves, weight of non-wrapper leaves, head length, head diameter, fresh weight of head, weight per plant and head yield. The results are presented. Data represented that Azotobacter + farmyard manure + NPK and phosphorus solubilizing microorganisms + digested sludge + NPK were more effective than Azotobacter + farmyard manure, phosphorus solubilizing microorganisms + digested sludge, Azotobacter + digested sludge, phosphorus solubilizing microorganisms + farmyard manure in case of growth (plant height, stem length, number of primary roots, number of wrapper leaves, number of non-wrapper leaves, weight of non-wrapper leaves) and yield (head length, head diameter, fresh weight of head, total weight/plant and head yield) contributing characters of cabbage.

The effects of organic-inorganic compound fertilizers and inorganic nitrogen fertilizers on the quality and yields of Chinese cabbage cv. Luxing Studied by Zhang (2004). The results show that application of organic-inorganic compound fertilizer I produced the highest yield among all treatments; the yield was higher by 14.4, 6.3, 10.6, 4.6 and 33.6% compared with the treatments of ammonium nitrate, ammonium sulfate, urea, organic-inorganic compound fertilizer II and the control, respectively. Among the three inorganic nitrogen fertilizers, the treatment of ammonium sulfate resulted in the highest yield. No significant difference in nitrate content of Chinese cabbage was observed between the treatments with nitrogen fertilizers of different N forms ( $P > 0.05$ ). Of all the nitrogen fertilizers of different N forms, organic-inorganic compound fertilizer I was absorbed by Chinese cabbage cv. Luxing at the highest apparent utilization rate of 29.7% (Zhang, 2004).

Cabbage cv. Vignesh plants were supplied with 100 and 75% recommended N rate, alone or in combination with biofertilizers (*Azospirillum brasilense* or *Azotobacter chroococcum*); 75 and 50% recommended N rate and/or cowdung manure, neem cake or poultry manure, alone or in combination with biofertilizers in a field experiment



conducted in Mohanpur, West Bengal, India during the rabi season of 2000-01. Crop yield was highest (55.82 t/ha) with the application of 50% recommended N + 25% poultry manure + biofertilizers, whereas benefit cost ratio was highest (4.30) was recorded with the application of 75% N + biofertilizers (Devi and Maity, 2003).

Greenhouse  $^{15}\text{N}$  isotope dilution was adopted to study nitrogen fertilizer utilization efficiency of organic and inorganic compound fertilizer. Results showed that nitrogen utilization efficiency of organic and inorganic compound fertilizers for Chinese cabbage (6.5-11.9%) was higher than that of inorganic compound fertilization. Application of organic and inorganic compound fertilizers increased yield of Chinese cabbage by 6.0-20%. Optimum proportion of organic fertilizer: inorganic fertilizer were 73:27 and 53:47, whereas optimum total nutrients (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) was selected as 15-20%. Application of such organic and inorganic compound fertilizer obtained the highest nitrogen fertilizer utilization efficiency (38.75%) (Jiang, 2005).

Six heat-tolerant cabbage cultivars were evaluated under plastic rain-shelters on mineral soils at MARDI Kluang, Johor, Malaysia. The cultivars were 'KK cross', 'Summer Autumn', 'King of Kings', 'Beijing Siji', 'Orient Express' and 'Magic Ball'. The normal fertilizer application system using 5 tons/ha of organic fertilizer (oil palm empty fruit bunch or EFB compost) as basal dressing supplemented with 1.5 tons/ha of NPK 12:12:17:2 compound fertilizer was compared to 20 tons/ha EFB compost and 0.3 ton/ha of NPK compound fertilizer. The results showed that 20 tons EFB compost/ha with 0.3 ton/ha inorganic fertilizer supplements resulted in higher yield and lower disease incidence compared to 5 tons compost/ha and 1.5 tons/ha of NPK fertilizer. Although 'Summer Autumn' resulted in highest yield of 25.8 tons/ha, its yield showed no significant difference with that of 'Beijing Siji', 'KK cross' and 'King of Kings', with yields ranging from 23.8 tons/ha to 24.6 tons/ha. 'Magic Ball' and 'Orient Express' produced significantly lower yields (13.3 tons/ha and 15.9 tons/ha respectively) than the rest. However, 'Magic Ball' and 'Orient Express' cultivars were relatively very tolerant to bacterial soft rot (*Erwinia carotovora*) attacks. The lowest tolerance to bacterial soft rot attacks was observed in 'Beijing Siji' (Yau, 2006).

Szafranek and Koterowa (1974) carried out an experiment to study the effect of commercial fertilizers in the presence or absence of FYM and legumes in rotation on yield and chemical composition of autumn white cabbage "Amager". The highest yield

of cabbage was recorded with the full fertilizer (NPK) treatment combined with liming every four years and with FYM and legumes in rotation. FYM and legumes increased the yield of cabbage by 378 q/ha.

Silva (1986) planted cabbage in hydromorphic soil treated with 100 kg /ha N, 100 kg/ha P<sub>2</sub>O<sub>5</sub>, 200 kg/ha K<sub>2</sub>O or 50 t/ha cattle manure, alone or in combination. N increased the total yield but decreased commercial to total yield ratio. K<sub>2</sub>O alone decreased total yields. Cattle manure increased commercial and total yields but decreased commercial to total yield ratio. The highest commercial yield (49 t/ha) was achieved with cattle manure or N + K<sub>2</sub>O but there was no response to P<sub>2</sub>O<sub>5</sub>.

Farooque and Islam (1989) carried out an experiment at the Horticulture Farm BAU, Mymensingh during 1987-88 to study the effect of spacing and different fertilizer management practices on the growth and yield of cabbage. The plants were spaced at 60 cm × 30 cm, 60 cm × 45 cm or 60 cm × 60 cm and were subjected to 3 different fertilization schedules. Application of cowdung 8.3 t/ha, mustard oil cake 200 kg, urea 326 kg, triple superphosphate 125 kg and 200 kg muriate of potash per hectare combinedly gave the highest marketable yield of cabbage.

The effects of composted cattle manure, rapeseed meal and mineral fertilizer applications on vegetables and soil fertility were examined from 1978 to 1987 by Yamada and Kamata (1989). They described that cabbage yields were higher with mineral fertilizer than other treatments, however, cabbage yields on the mineral fertilizer plot decreased without the application of agricultural chemicals, whereas yields on cattle manure and rapeseed meal plots were not affected. Lettuce and onion yields were the same with rapeseed meals as with mineral fertilizers. Lettuce yield was lower, and onion yields varied annually with the cattle manure treatment. Cattle manure plots showed p<sup>H</sup> value of 6.8 whereas p<sup>H</sup> values decreased on the other plots having fertilizer + cattle manure. Total C and N also increased in the cattle manured plot, but were constant on the fertilizer treated ones. Available N and biomass C increased on the cattle manure plot but decreased on the fertilized plot. Soil density and solid phase ratio decreased and porosity increased on the manure plot. The results showed the benefit of using organic soil conditioner with manures compared with manures alone.

It was reported that the highest cabbage yield (76.60 t/ha) was found from the combined effect of 180 kg N, 60 kg P, 180 kg K per hectare and cowdung @ 5 t/ha (Anon., 1990) and it was also stated that a combination of organic and inorganic fertilizer was better than a single fertilizer for cabbage production.

In another study (Anon., 1991), it was found that fertilizer at the rate of 240 kg N/ha, 60 kg P/ha and 120 kg K/ha along with 5 t/ha cowdung gave the highest head yield (75 t/ha) of cabbage var. Atlas-70.

Kolota *et al.* (1992) reported that yields of three crops (cabbage, celery and beet) were higher on plots receiving 50 t/ha FYM + mineral fertilizers compared with plots receiving only mineral fertilizers.

Use of organic fertilizers ensures the sustainable agriculture as has been reported by Abedin *et al.* (1994). They conducted a study to find out the sustainable practices using data collected from 85 selected farmers in Cameroon, involved in pest (insect, disease, weed) control, fertilization and soil erosion control. Results indicated that use of less agricultural chemicals and inorganic fertilizers were more sustainable practices and farmers who used these did not suffer yield losses.

Suchorska (1996) conducted a field experiment to test the sustainability of some unconventional fertilizers obtained from brown coal, brown coal ash, poultry manure, cattle manure and fertilizer made from mushroom substrate. In the 3 years trial, the yield and content of P, K, Ca and Mg in cabbages, carrots and spinach were determined and found that the highest yield of white cabbage and spinach was obtained from the plots fertilized with brown coal ash. The mineral organ fertilizers tested increased the P content of the vegetables.

During winter season, an experiment was conducted by Asumus and Gorltiz (1986) at Gross Kretutz, Germany to find out the effect of equivalent rates of mineral fertilizer, FYM and mixture of two nitrogen forms on yield, N uptake and utilization in the rotation potatoes/winter wheat/sugarbeet/spring barely. They observed that combined application of FYM and mineral fertilizer increased yield and decreased uptake compared with FYM or mineral fertilizer alone.

Only one experiment for 16 years conducted by Rauhe *et al.* (1987) at Sechhausen near, Peipzig, and applied an average amount of 0, 51, 102 or 153 kg FYM and 0, 53, 106 or 159 kg mineral N/ha. They observed that the combination of about 100 kg FYM + 120 kg mineral N ensure both high yield and maintained soil N content.

An experiment was conducted for 3 years considering five replications of two treatments (organic and conventional) annually where yield and vitamin content of carrot and cabbage were not affected by treatments (Worman and Havard , 1997).

Kropisz (1992) carried out an experiment using composted pine bark (CPB) + vegetable matter, composted sawdust (CS) + vegetable matter (added to CPB and CS at 10, 20 or 30% by volume) and FYM were applied at 25 t/ha in 3-year field trials with cabbage, onion and carrot. All the 'organic fertilizers were applied in the first year only. NPK fertilizers were applied annually and there were plots where NPK alone was applied. Organic fertilizers in all cases improved cropping, with the highest average yields being obtained on plots receiving FYM + NPK. These were 50.2, 28.3 and 31.5 t/ha for cabbage, onions and carrots, respectively.

While conducting an experiment in Bangladesh Agricultural University, Mymensingh Aditya (1993) reported that the highest (60 t/ha) yield of cabbage (var. Atlas-70) was obtained by the application of 375 kg N/ha 225 kg P/ha and 225 kg K/ha along with cowdung at the rate of 10 t/ha.

Kamiyama *et al.* (1995) carried out experiment in upland fields and lowland fields, over 15 and 17 years respectively. Mineral fertilizers were applied with or without FYM to cabbage, sweet corn and rice. In the upland fields, cabbage and sweet corn yields were maximum when chemical fertilizers were applied with FYM. In the lowland rice fields, yields were similar with and without FYM.

Hsieh *et al.* (1995) investigated the continuous use of organic manure on the growth and yield of cabbage and showed that the increase in cabbage yields in the organic plots compared with chemical plots were greater, especially when the micro-organism mixture was included to the manures. Among the compost, cabbage performed best with chicken manure compost combined with microorganisms (5 kg/m<sup>2</sup>).

Asiegbu and Oikeh (1995) showed that NPK fertilizer were more efficient than the organic manures in supplying N, P and K at least in the short run, while the organic manure had an advantage in supply of other macro and micro nutrient elements not contained in NPK fertilizer.

Aktar *et al.* (1996) carried out an experiment at Joydebpur during the rabi season of 1993-94 and 1994-95 to find out the effects of poultry manure (PM) and cowdung (CD) in presence and absence of chemical fertilizer on growth and yield of broccoli and reported that 10 t/ha of poultry manure with recommended dose of nutrients produced the highest curd yield of broccoli. The application of only PM and CD caused yield depression even at higher doses. The highest curd yield of 20.70 and 16.7 tons per hectare were obtained with PM and CD against 9.0 tons per hectare in the control treatment. In absence of NPKs only organic manure could not produce higher yield of curd.

Wang-Xiude *et al.* (1996) conducted an experiment on 5 formulations of fertilizer on 4 vegetables namely cucumber, cabbage, tomato and cauliflower. The formulation containing 88% powdered poultry manure, 4% urea, 4% KCl and 4% boron sulphate was the best for vegetable growth. This formulation was applied to autumn cabbage, autumn cucumber and white gourd at different application rates (0, 112.5, 225, 337.5 or 450 kg/100m<sup>2</sup>) where 337.5 kg/m<sup>2</sup> gave the best results.

Dixit (1997) showed that the yield of cabbage increased with increasing N (from 136.8 to 175.1 q/ha after addition of 0 and 160 kg N/ha respectively) and FYM rate (from 129.5 to 144 q/ha). Addition of FYM to N treatments further increased yield (Yields of 176.1 q/ha in presence of FYM + 160 kg N/ha).

The effects of compost and inorganic fertilizer on the growth, yield and pest damage on cabbage intercropped with tomatoes were investigated by Busayong (1996). He pointed out that no significant differences were observed in the yield, growth and pest damage of cabbage applied with compost only or inorganic fertilizers only or mixture of composts and inorganic fertilizers.

Farid *et al.* (1998) conducted an experiment at Joydebpur to study the efficiency of poultry manure and cowdung alone and in combination with mineral fertilizers on the

yield of cabbage (var. Atals-70). They mentioned that the head yield of cabbage was increased both by cowdung and poultry manure with macro and micro-nutrients added to the treatments. But the increase due to poultry manure was always higher than that of cowdung. Poultry manure alone increased the yield significantly when it was applied at the rate of 20 t/ha.

Economically the treatments using 5 t/ha of poultry manure along with 200, 120, 100 and 50 kg/ha of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O and S, respectively. Thus organic manures gave significantly higher yield of cabbage and more profit when applied in combination with mineral fertilizers.

Quattrucci and Canali (1998) conducted an experiment with traditional mineral fertilizers and mixture of organic and mineral fertilizers to evaluate their effects on cabbage. They reported that mixture of organic and mineral fertilizers gave the highest total and marketable yields.

Kabir (1998) carried out an experiment at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh to find out the effect of poultry manure and cowdung in presence and absence of chemical fertilizer on growth and yield of cabbage and reported that combination of poultry drops and inorganic fertilizer performed the best in respect of number of leaves, head diameter, plant height, number of folded leaves, head weight and percent of dry matter.

Azad (2000) conducted an experiment at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh, during the period from November to March 2000. He found the maximum plant height, plant spread, number of total loose and healthy leaves, diameter and thickness of head, length and diameter of stem, number of roots, fresh and dry weight of roots, gross and marketable yield of cabbage when organic manures and inorganic fertilizers were used in combination.

Hague (2000) studied the effect of differ fertilizer management practices on the growth and yield of cabbage at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh. The experiment was consisted of different combinations of organic and inorganic fertilizers. He reported that 1/4cowdung +1/4 mustard oil cake +1/4 poultry drop +1/4 NPK performed the best in respect of plant height and spread, days required

for head formation and maturity, number of loose leaves, diameter and thickness of head, fresh and dry weight of head, marketable yield per plant and per hectare.

Sannigrahi and Borah (2000) conducted a field experiment in Assam with tomatoes, French beans and cabbage by the application of organic manures (FYM or compost) with or without NPK fertilizer and root inoculation with mycorrhizas. They reported that tomato yield was the highest (17.3 t/ha) with the application of recommended NPK fertilizer, while the yield of French hears (36.1 t/ha) and cabbage (26.6 t) were highest with 10 t FYM/ha + Inoculation + 15 kg N + 10 kg K<sub>2</sub>O and 10 t compost + Inoculation + 40 kg N + 30 kg K<sub>2</sub>O, respectively.

Considering the available information so far collected from home and abroad it was evident that the different sources of nutrient (NPK fertilizers, cowdung; poultry manure etc.) greatly influenced the growth and yield of some vegetables including cabbage. The organic nutrient sources increased soil humus and organic matter content, conserved soil moisture and increased soil fertility and inorganic fertilizers use efficiency. Various kinds of nutrient sources are available which are easily applicable in vegetable crops as well as field crops. But in Bangladesh context, the illiterate farmers have no sound knowledge on nutrient sources and in most case they only use inorganic fertilizer without considering nutrient source, crop, environmental interactions and cost benefit ratio.

## **CHAPTER 3**

### **MATERIALS AND METHODS**

Materials and methods are the key factors in conducting a research. Appropriate methodology enables the researchers to collect valid and reliable information and to analyze the information properly in order to conclude the findings. 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 this section are described below in the following subheadings:

#### **3.1 Description of the experimental site**

##### **3.1.1 Location**

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

##### **3.1.2 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<sup>H</sup> was 5.35. The details soil properties are presented in Appendix-I.

##### **3.1.3 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 (08 November, 2016 to March, 2017) are included in the Appendix-II.

#### **3.2 Experimental period**

Duration of the experiential period was from November 2016 to March 2017.

#### **3.3 Planting material**

Three varieties were used as planting materials viz. (i) 75 Cabbage, (ii) Succession Taki and (iii) Succession Japoni.



### 3.4 Raising of seedlings

Seedlings were raised in seedbed of Departmental research field of Agroforestry and Environment. The soil was pulverized and converted into loose fragile and dried mass by spading. All weeds and stubbles were removed from the soil.

### 3.5 Experimental design & Layout

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. Total numbers of experimental plot were thirty six. The size of each unit plot was 3m x 2m. So the total area of each plot was 6m<sup>2</sup>. The Layout of the experiment is shown in Figure-1.

### 3.6 Experimental treatment

The following treatments were included in the experiment:

#### FACTOR-A (Three Varieties)

V<sub>1</sub> = 75 Cabbage

V<sub>2</sub> = Succession Taki

V<sub>3</sub> = Succession Japani

#### FACTOR-B (Four Fertilizer & Manure Applications)

F<sub>1</sub> = no fertilizer, no manure and no pesticide

F<sub>2</sub> = cow dung and bio-pesticide

F<sub>3</sub> = poultry and bio-pesticide

F<sub>4</sub> = recommended chemical fertilizer and chemical pesticide

#### Treatments combinations:

So, there were 12 (twelve) treatment combinations. These were as follows:

V<sub>1</sub>F<sub>1</sub> = 75 Cabbage + no fertilizer, no manure and no pesticide

V<sub>1</sub>F<sub>2</sub> = 75 Cabbage + cow dung and bio-pesticide

V<sub>1</sub>F<sub>3</sub> = 75 Cabbage + poultry and bio-pesticide

V<sub>1</sub>F<sub>4</sub> = 75 Cabbage + recommended chemical fertilizer and chemical pesticide

V<sub>2</sub>F<sub>1</sub> = Succession Taki + no fertilizer, no manure and no pesticide

V<sub>2</sub>F<sub>2</sub> = Succession Taki + cow dung and bio-pesticide

V<sub>2</sub>F<sub>3</sub> = Succession Taki + poultry and bio-pesticide

V<sub>2</sub>F<sub>4</sub> = Succession Taki + recommended chemical fertilizer and chemical pesticide

V<sub>3</sub>F<sub>1</sub> = Succession Japani + no fertilizer, no manure and no pesticide

V<sub>3</sub>F<sub>2</sub> = Succession Japani + cow dung and bio-pesticide

V<sub>3</sub>F<sub>3</sub> = Succession Japani + poultry and bio-pesticide

V<sub>3</sub>F<sub>4</sub> = Succession Japani + recommended chemical fertilizer and chemical pesticide

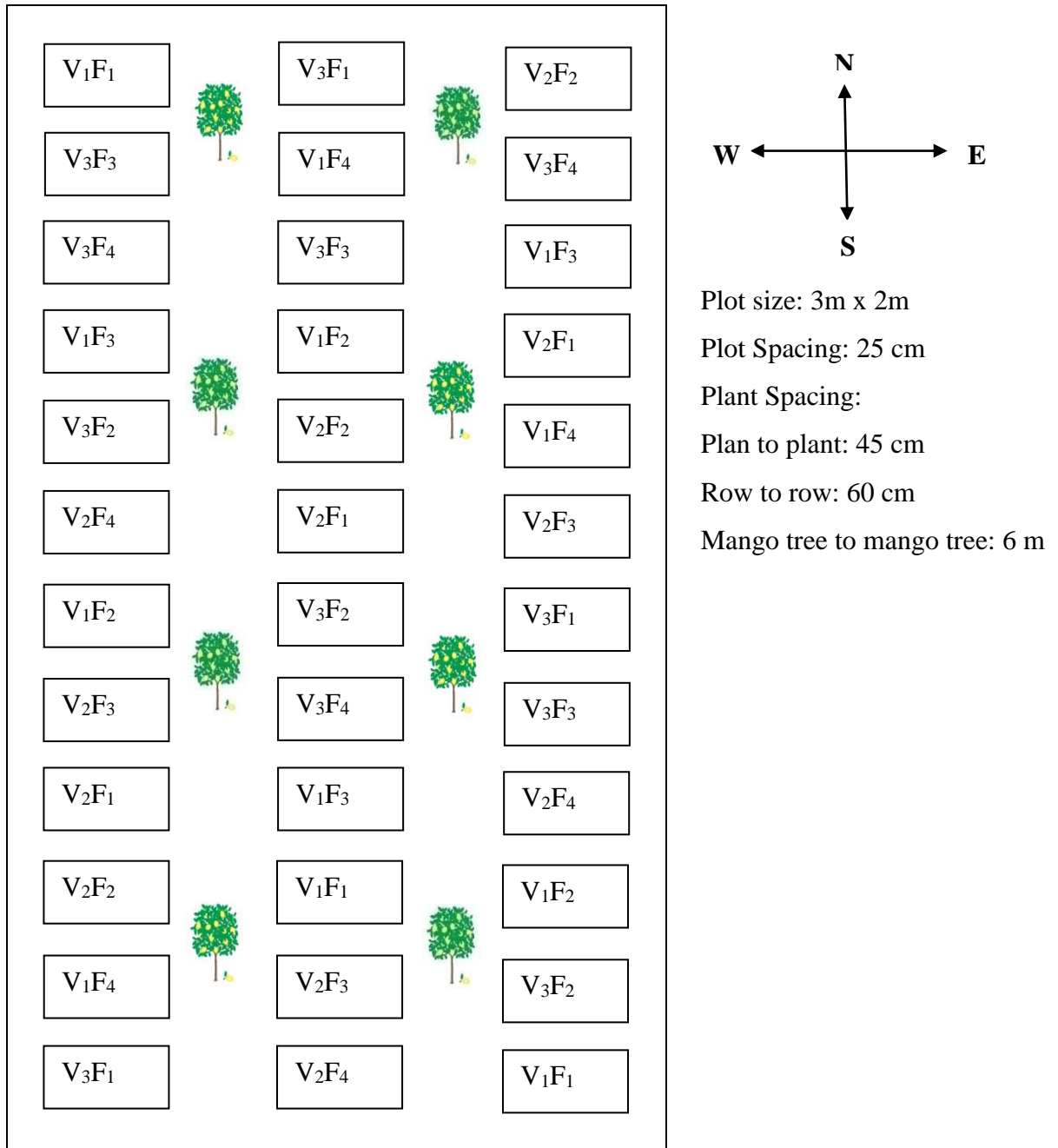


Figure 1. Layout of the Experiment

### 3.7 Tree characteristics

#### General characteristics of Mango tree

**Scientific name:** *Mangifera indica*

**Family:** Anacardiaceae (cashew family)

**Common name:** It has been grown throughout tropical and subtropical world for thousands of years and has become integral part of many cultures. There are many different names for mangoes around the world today it reflects the cultures and languages spoken by people who grow them. Many of the names for have common derivations, reflecting the origins and spread of the mango tree along with the spread of human communities.

**Distribution:** All tropical and subtropical regions.

**Size:** Mango are long-lived evergreen trees that can reach heights of 15-30 m (50-100ft). Most cultivated mango trees are between 3 and 10 m (10-33) tall when fully mature depending on the variety and the amount of pruning. Wild non-cultivated seedling trees often reach 15 m (50) when found in favorable climates, and they can live for over 100 years and develop trunk girths of over 4m (13ft).

**Habitat:** Grows from sea level to 1200m (3950ft) tropical latitudes; however, most commercial varieties are grown below 600m (1950ft); rainfall 400-3600mm (16-140in), fruits best with a well-defined winter dry period.

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

**Roots:** The Mango 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.

**Growth rate:** Fast, >1.5 m/yr (5 ft/yr) in ideal conditions.

**Main agroforestry uses:** Home gardens, silvopasture.

**Main uses:** Fruit, flavoring, medicinal, timber.

#### Health benefits of mango:

- Mango is one of the major source of vit-A in Bangladesh. Most of the people eat it easily from their home garden.
- Mango, like citrus fruits, is an excellent source of vitamin C; 100 g fresh fruits provide 71.5 mg or 119% of daily-recommended value. Studies suggest that

consumption of fruits rich in vitamin C helps the human body develop resistance against infectious agents and scavenge harmful, pro-inflammatory

- Mango fruit contains 70 calories per 100 g, comparable to that in the table grapes. It has no saturated fats or cholesterol, but composes of good amounts of dietary fiber, vitamins, and antioxidants etc
- Research studies suggest that oligonol, a low molecular weight polyphenol, is found abundantly in litchi fruit. Oligonol is thought to have anti-oxidant and antiinfluenza virus actions. In addition, it helps improve blood flow in organs, reduce weight, and protect skin from harmful UV rays.
- Further, it is a very good source of B-complex vitamins such as thiamin, niacin, and folates. These vitamins are essential since they function by acting as cofactors to help the body metabolize carbohydrates, protein, and fats.

**Yields:** Typically, yields are often less than (1b) of fruit in heavy cropping years and as low as 4 kg in bad years.

**Soils:** Tolerates a range of soils; optimal p<sup>H</sup> 5.5-7.5.

**Intercropping:** Compatible with other similarly vigorous species, as well as animal grazing.

**Invasive potential:** Not an aggressively invasive species.

#### **Field characteristics of Mango tree**

Planting orientation	: North-South
Mango variety	: Amropali
Age of mango tree	: 8 years
Spacing	: 6m × 6m
Average plant height	: 6.11m
Average basal diameter	: 13.06 cm
Average canopy diameter	: 255.6 cm

### **3.8 Land preparation**

The land of experimental plot was opened in the first week of November 2016 with a power tiller and it was made ready for planting on 14 November 2016. 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.

### **3.9 Fertilizer and manure applications**

Application of manure and fertilizers were applied as per treatment. Doses of organic manures and inorganic fertilizers applied in the field according to the treatments were as follows:

(i) Control : No manures and fertilizer were applied

(ii) Cowdung: 15 t/ha

(iii) Poultry manure: 10 t/ha

(iv) Chemical fertilizer :

Urea – 330 kg/ha

TSP – 200 kg/ha

MOP – 250 kg/ha

### **3.10 Transplanting and crop management**

Healthy and uniform sized seedlings were transplanted in the main field. The seedlings were uprooted carefully from the seedbed to avoid any damage to the root system. To minimize the roots damage of the seedlings, the seedbed was watered one hour before uprooting the seedlings. Transplanting was done in the afternoon carefully. A considerable number of seedlings were also planted in the border of the experimental plots for gap filling if necessary later on.

### **3.11 Intercultural operations**

#### **3.11.1 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.

#### **3.11.2 Gap filling**

When the cabbage seedlings were well established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy seedlings of the same stock material grown in nearby plot where initial planted seedlings failed.

### **3.11.3 Irrigation**

Cabbage should be irrigated immediately after sowing or transplanting. Thereafter, irrigation should be applied at intervals of 10 to 12 days in heavy soils or eight days in light soils and the schedule should be followed until the heads are fully developed and firm. Young plants should receive enough water for vegetative growth before forming heads. Excess moisture when the heads have formed may cause them to crack.

### **3.11.4 Plant protection measures**

In case of inorganic cabbage plots, neem oil (2%) were applied as bio pesticide. In case of chemical fertilizer and chemical pesticide plots, for controlling leaf caterpillars *Nogos* @ 1 ml/L water were applied two times at an interval of 10 days starting soon after the appearance of infestation. The bio pesticide and insecticides were applied fortnightly as a routine work from a week after transplanting to a week before first harvesting.

### **3.12 Harvesting**

All cabbage head were not matured at a same time, it could not be done at a time from the whole field. Harvesting was done when necessary. Harvesting was started on 19 February and completed by 22 March, 2017. Hand harvesting was done from each plot.

### **3.13 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.

#### **3.13.1 Plant height (cm)**

The heights of the plants were measured from plants of each plot after 15 days of transplanting and up to 75 days after transplanting at 15 days interval. The height was measured from the soil surface to the tip the plant.

#### **3.13.2 Number of leaves per plant**

The number of leaves per plant was counted individually after 15 days of transplanting and continued up to 45 days after transplanting at an interval of 15 days.

**3.13.3 Length of the largest leaf (cm)**

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

**3.13.4 Breadth of the largest leaf (cm)**

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

**3.13.5 Length of root (cm)**

The length of the root was measured with the help of centimeter scale at harvest.

**3.13.6 Length of stem (cm)**

The length of the stem was measured with the help of centimeter scale at harvest.

**3.13.7 Size of the head (cm)**

The size of the head was measured with a slide calipers from the neck of the head of the bottom of ten selected marketable head from each plot, and their average was calculated in centimeter.

**3.13.8 Yield per plant (g)**

The yield per plant was calculated in g by averaging the weights by 10 harvesting heads.

**3.13.9 Yield per hectare (ton)**

The yield per ha was calculated in ton from the yield per unit plot.

**3.14 Total cost of production**

The cost of cultivation of the mango tree was worked out on the basis of per hectare. The initial plantation cost of the mango sapling was included in this study. The management cost of mango 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.

**3.14.1 Gross return**

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

**3.14.2 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.

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

**3.14.3 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)

$$\text{Benefit-cost ratio} = \text{Gross return (Tk.ha}^{-1}\text{)} / \text{Total cost of production (Tk.ha}^{-1}\text{)}.$$

**3.15 Statistical analysis**

The data collected from the experiment in respect of various characters were statistically analyze with the help of computer using the MSTAT-C program to find out the difference among the treatment means. The analysis of variance for most of the characters under consideration was performed by F-test. The difference between pairs of means was evaluated by DMRT test (Gomez and Gomez, 1984).



## **CHAPTER 4**

### **RESULTS AND DISCUSSION**

The results of the performance of three cabbage varieties influenced by different fertilizer and manure applications under mango based agroforestry system are presented in Table 1 to 18. The findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield and quality parameters 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 Cabbage**

##### **4.1.1 Plant height (cm)**

Plant height is an important growth parameter for the yield and quality of cabbage. At different days after transplanting (DAT), plant height was significantly influenced by different varieties of cabbage (Table 1). At 15 DAT, the tallest (11.70 cm) plant was recorded from the variety 75 Cabbage ( $V_1$ ) which was significantly followed by variety Succession Japan ( $V_3$ ) whereas the shortest (10.75 cm) plant height was demonstrated with variety Succession Taki ( $V_2$ ). Similar trend of increasing plant height was observed at 30 and 45 DAT, the tallest plant (20.35 cm and 24.20 cm) was recorded from the variety 75 Cabbage ( $V_1$ ) which was significantly followed by variety Succession Japan ( $V_3$ ). On the other hand, the shortest (16.64 cm and 19.44 cm) plant height was recorded with variety Succession Taki ( $V_2$ ). Again, at 60 DAT, the tallest plant (34.60 cm) was recorded from the variety Succession Japan ( $V_3$ ) which was significantly followed by variety 75 Cabbage ( $V_1$ ) and the shortest (23.85 cm) plant height was demonstrated with variety Succession Taki ( $V_2$ ). At 75 DAT, the tallest plant (40.01 cm) was recorded from the variety 75 Cabbage ( $V_1$ ) which was significantly followed by variety Succession Japan ( $V_3$ ) whereas the shortest (32.42 cm) plant height was demonstrated with variety Succession Taki ( $V_2$ ). The varietal effect on plant height was supported by Haque, 2005.

**Table 1: Main effect of variety on plant height of cabbage at different DAT**

Treatments (Variety)	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
75 Cabbage (V <sub>1</sub> )	11.70 a	20.35 a	24.20 a	33.68 a	40.01 a
Succession Taki (V <sub>2</sub> )	10.75 b	16.64 b	19.44 b	23.85 b	32.42 b
Succession Japani (V <sub>3</sub> )	11.57 a	19.49 a	23.90 a	34.60 a	39.88 a
CV (%)	7.24	11.12	10.73	13.99	7.41

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.1.2 Number of leaves plant<sup>-1</sup>

Number of leaves plant<sup>-1</sup> is an important parameter considering the highest performance of cabbage yield (Table 2). Cabbage variety Succession Taki (V<sub>2</sub>) gave the highest (6.94, 12.65 and 17.33) number of leaves plant<sup>-1</sup> at all growth stages of cabbage varieties which was significantly followed by variety Succession Japani (V<sub>3</sub>). On the contrary, the lowest (11.83 and 15.63) number of leaves plant<sup>-1</sup> at 30 and 45 DAT was obtained with variety 75 Cabbage (V<sub>1</sub>). These results might be due to cause of genetical characters of varieties that caused higher and lower number of leaves plant<sup>-1</sup>.

**Table 2: Main effect of variety on number of leaves of cabbage at different DAT**

Treatments (Variety)	Number of leaves plant <sup>-1</sup>		
	15 DAT	30 DAT	45 DAT
75 Cabbage (V <sub>1</sub> )	6.82	11.83	15.63 b
Succession Taki (V <sub>2</sub> )	6.94	12.65	17.33 a
Succession Japani (V <sub>3</sub> )	6.60	11.96	16.17 ab
CV (%)	7.00	8.02	11.16

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

### 4.1.3 Length of the largest leaf (cm)

Leaf length plant<sup>-1</sup> is one of the important parameter for measuring yield performance of cabbage variety (Table 3). Leaf length per plant was significantly influenced by different cabbage varieties only at 45 DAT and 60 DAT but at 15 DAT and 30 DAT not significantly different. Different varieties showed different leaf length at different growth stages. In case of at 15 DAT, it was measured that variety Succession Japani (V<sub>3</sub>) demonstrated the highest (6.11 cm) leaf length per plant which was followed by variety Succession Taki (V<sub>2</sub>) and the lowest (6.03 cm) leaf length was recorded from variety 75 Cabbage (V<sub>1</sub>). At 30 DAT, the highest (12.19 cm) length of the largest leaf was recorded from variety 75 Cabbage (V<sub>1</sub>) whereas the lowest (11.32 cm) length was recorded from variety Succession Taki (V<sub>2</sub>). At 45 DAT and 60 DAT, the highest (20.20 and 27.69 cm) length of the largest leaf was recorded from variety 75 Cabbage (V<sub>1</sub>) which was significantly followed by variety Succession Japani (V<sub>3</sub>) whereas the lowest (15.58 and 19.14 cm) length of the largest leaf was recorded from variety Succession Taki (V<sub>2</sub>). The results obtained from the experiment on leaf length of the largest leaf might be due to cause of varietal effect, soil type, nutrient availability etc. and this results are agreement with Muhammad and Javed, 2001.

**Table 3: Main effect of variety on length of the largest leaf of cabbage at different DAT**

Treatments (Variety)	Length of the largest leaf (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
75 Cabbage (V <sub>1</sub> )	6.03	12.19	20.20 a	27.69 a
Succession Taki (V <sub>2</sub> )	6.05	11.32	15.58 b	19.14 b
Succession Japani (V <sub>3</sub> )	6.11	11.57	19.09 a	27.20 a
CV (%)	10.67	12.12	13.91	12.39

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.1.4 Breadth of the largest leaf (cm)

Cabbage leaf breadth was also influenced due to their varietal characters (Table 4). At 15 DAT, the highest (5.04 cm) leaf breadth was recorded from the variety Succession Taki ( $V_2$ ) whereas the minimum (4.51 cm) breadth of leaf was observed from variety 75 Cabbage ( $V_1$ ). In case of at 30 DAT, the highest (9.60 cm) leaf breadth was recorded from the variety Succession Taki ( $V_2$ ) whereas the minimum (8.98 cm) breadth of leaf was observed from variety Succession Japan ( $V_3$ ). At 45 DAT, the widest leaf (12.77 cm) was recorded from the variety 75 Cabbage ( $V_1$ ). On the other hand, the lowest (12.50 cm) breadth of leaf was recorded with variety Succession Taki ( $V_2$ ). Again at 60 DAT, the widest leaf (21.88 cm) was recorded from the variety 75 Cabbage ( $V_1$ ) which was significantly followed by Succession Japan ( $V_3$ ). On the other hand, the lowest (17.84 cm) breadth of leaf was recorded with variety Succession Taki ( $V_2$ ). The results obtained from the experiment on leaf breadth of the largest leaf might be due to cause of varietal effect, soil type, nutrient availability etc.

**Table 4: Main effect of variety on breadth of the largest leaf of cabbage at different DAT**

Treatments (Variety)	Breadth of the largest leaf (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
75 Cabbage ( $V_1$ )	4.51	9.41	12.77	21.88 a
Succession Taki ( $V_2$ )	5.04	9.60	12.50	17.84 b
Succession Japan ( $V_3$ )	4.68	8.98	12.61	20.89 a
CV (%)	13.23	13.41	12.93	11.58

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.1.5 Length of root (cm)

Root length is an important plant character for contributing higher yield performance and it differs with varieties in accordance with the genetical characters of the variety. Root length was significantly influenced by different cabbage varieties (Table 5). Different

varieties showed different root length and it was observed at the time of harvest. It was defined that variety 75 Cabbage ( $V_1$ ) verified the highest (17.36 cm) root length at harvest which was significantly followed by variety Succession Japani ( $V_3$ ). But the lowest (12.25 cm) root length among the varieties was obtained with variety Succession Taki ( $V_2$ ) at harvest. The results was represented under the present experiment might be due to cause of water and nutrient availability on soil characteristic that cause higher and lower root length of plants.

**Table 5: Main effect of variety on length of root (cm), length of stem (cm) and size of head (cm) of cabbage at different DAT**

Treatments (Variety)	Root length (cm)	Stem length (cm)	Size of head (cm)
75 Cabbage ( $V_1$ )	17.36 a	3.65	113.10
Succession Taki ( $V_2$ )	12.25 b	3.43	112.20
Succession Japani ( $V_3$ )	15.38 a	3.67	115.80
CV (%)	15.73	7.59	4.90

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.1.6 Length of stem (cm)

Stem length is also an important phenotypic plant character controlled genetically which differs within the varieties. Stem length was influenced by different cabbage varieties (Table 5). Different varieties showed different stem length and it was deliberate at the time of harvest. It was defined that variety Succession Japani ( $V_3$ ) verified the highest (3.67 cm) stem length at harvest which was closely followed by variety 75 Cabbage ( $V_1$ ) and the lowest (3.43 cm) stem length among the varieties was obtained from the variety Succession Taki ( $V_2$ ) at harvest. Varietal effect was observed on stem length due to its phenotypical characters (Haque, 2005) and this result on stem length is supported by Haque, 2005.

#### 4.1.7 Size of the head (cm)

The important yield contributing character of cabbage is size of the head (Table 5). The highest (115.80 cm) size of the head was recorded from variety Succession Japani ( $V_3$ ) at harvest which was closely followed by variety 75 Cabbage ( $V_1$ ) and the lowest (112.20

cm) size of the head among the varieties was obtained from variety Succession Taki ( $V_2$ ) at harvest. Head is a measurement of the size of actual cabbage shape which indicates yield amount and/or market value. Size of the head was affected significantly by the different shade levels. Similar results were obtained by Haque, 2005 and Muhammad and Javed, 2001 with their experiments.

#### 4.1.8 Weight per plant (g)

Determination of whole plant weight is an important measurement for comparing yield performance among the cabbage varieties under the present study. The result showed that weight of plant was significantly affected by the different varieties (Table 6). The highest (1652.00 g) weight of plant was recorded in variety Succession Japani ( $V_3$ ) which was significantly followed by variety 75 Cabbage ( $V_1$ ) and the lowest (1198.00 g) weight of plant was recorded from variety Succession Taki ( $V_2$ ).

**Table 6: Main effect of variety on weight per plant (g), weight of plant (ton ha<sup>-1</sup>) and yield of head (g) of cabbage at different DAT**

Treatments (Variety)	Weight per plant (g)	Weight of plant (ton ha <sup>-1</sup> )	Yield of head (g)
75 Cabbage ( $V_1$ )	1591.00 a	79.12 a	916.30 a
Succession Taki ( $V_2$ )	1198.00 b	61.24 b	792.40 b
Succession Japani ( $V_3$ )	1652.00 a	82.31 a	947.00 a
CV (%)	13.42	12.61	9.70

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.1.9 Weight of plant (ton ha<sup>-1</sup>)

The weight of cabbage (ton ha<sup>-1</sup>) was significantly affected by the different varieties (Table 6). The highest (82.31 ton ha<sup>-1</sup>) weight of plant was recorded in variety Succession Japani ( $V_3$ ) which was significantly followed by variety 75 Cabbage ( $V_1$ ) and the lowest (61.24 ton ha<sup>-1</sup>) weight of plant was recorded from variety Succession Taki ( $V_2$ ). Supported results with the present study was achieved by Haque, 2005, Muhammad and Javed, 2001.

#### 4.1.10 Yield of head (g)

The result showed that marketable yield of head was significantly affected by the different varieties used in the present experiment (Table 6). The highest (947.00 g) yield of head was recorded in variety Succession Japani ( $V_3$ ) which was significantly followed by variety 75 Cabbage ( $V_1$ ) and the lowest (792.40 g) yield of head was recorded from variety Succession Taki ( $V_2$ ). The results achieved by Haque, 2005, Muhammad and Javed, 2001 was similar to the present study.

#### 4.1.11 Yield of head (ton ha<sup>-1</sup>)

The yield of head (ton ha<sup>-1</sup>) was significantly affected by the different varieties (Fig. 1). The highest (47.45 ton ha<sup>-1</sup>) yield of head was recorded in variety Succession Japani ( $V_3$ ) which was significantly followed by variety 75 Cabbage ( $V_1$ ) and the lowest (40.15 ton ha<sup>-1</sup>) yield of head was recorded from variety Succession Taki ( $V_2$ ).

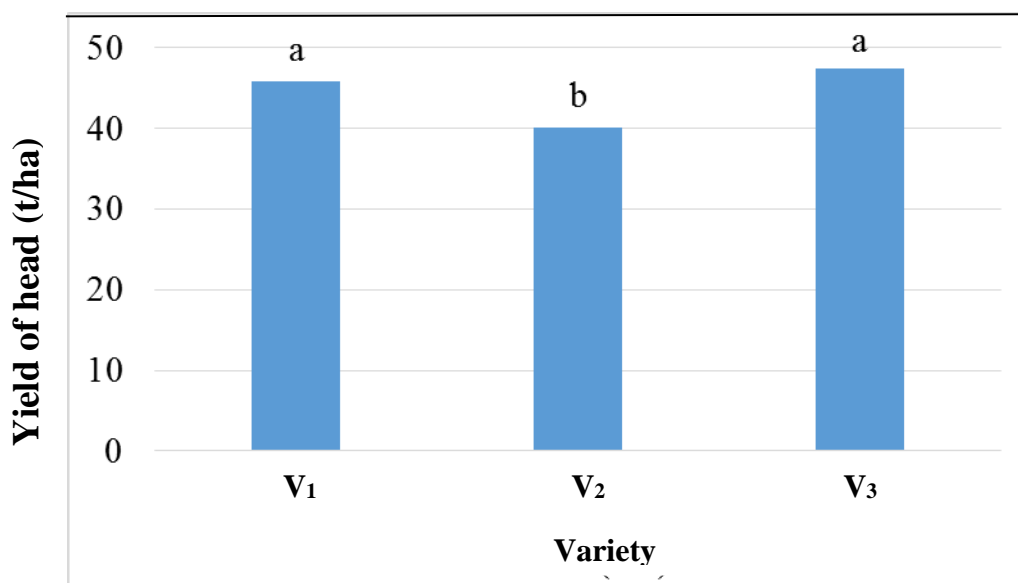


Fig. 1. Yield of head (ton ha<sup>-1</sup>) influenced by different cabbage varieties

## 4.2 Main effect of fertilizer and manure applications on growth, yield contributing characters and yield of Cabbage

### 4.2.1 Plant height (cm)

Fertilizer is the most important factor for achieving the desired yield of crop. Plant height is another important growth parameter considering performance. Plant height was significantly affected by different fertilizer & manure applications. At different days after transplanting (DAT), plant height was significantly influenced by different treatments (Table 7). It is evident that plant height was the highest (12.72, 21.74, 26.85, 36.83 and 42.45 cm) with the treatments of chemical fertilizer and chemical pesticide (F<sub>4</sub>) at 15, 30, 45, 60 and 75 DAT of different cabbage varieties. On the other hand, the lowest (10.28, 15.95, 17.62, 25.15 and 32.97 cm) plant height at 15, 30, 45, 60 and 75 DAT and respectively was with the treatments of no fertilizer, no manure and no pesticide (F<sub>1</sub>). This result might be due to cause of rapid performance on growth characters and rapid release of nutrients of inorganic fertilizer for plant height where organic fertilizer has slow nutrient release capacity that caused lower plant height. Results under the present experiment on plant height was supported by Souza *et al.* (2008).

**Table 7: Main effect of fertilizer & manure applications on plant height of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	10.28 c	15.94 c	17.62 c	25.15 c	32.97 c
Cow dung and bio-pesticide(F <sub>2</sub> )	10.93 bc	18.15 b	20.99 b	28.62 bc	35.96 b
Poultry and bio-pesticide(F <sub>3</sub> )	11.43 b	19.47 b	24.59 a	32.24 b	38.36 b
Chemical fertilizer and chemical pesticide (F <sub>4</sub> )	12.72 a	21.74 a	26.85 a	36.83 a	42.45 a
CV (%)	7.24	11.12	10.73	13.99	7.41

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.



### 4.2.2 Number of leaves plant<sup>-1</sup>

It was measured that (Table 8) the highest (7.22, 12.88 and 18.43) number of leaves plant<sup>-1</sup> was obtained with the treatments of chemical fertilizer and chemical pesticide (F<sub>4</sub>) at 15, 30 and 45 DAT respectively which was statistically identical with treatment of poultry and bio-pesticide (F<sub>3</sub>) at all growth stages of cabbage varieties. The lowest (6.34, 11.28 and 14.28) number of leaves plant<sup>-1</sup> was found to be at 15, 30 and 45 DAT respectively with the treatments of no fertilizer, no manure and no pesticide (F<sub>1</sub>). The results obtained from the experiment on number of leaves plant<sup>-1</sup> was conformity with Vimala, 2006, Pankaj, 2006 and Muhammad and Javed, 2001.

**Table 8: Main effect of fertilizer & manure applications on number of leaves plant<sup>-1</sup> of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Number of leaves plant <sup>-1</sup>		
	15 DAT	30 DAT	45 DAT
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	6.34c	11.28 c	14.28 c
Cow dung and bio-pesticide (F <sub>2</sub> )	6.62bc	11.76 bc	15.59 bc
Poultry and bio-pesticide(F <sub>3</sub> )	6.96 ab	12.68 ab	17.20 ab
Chemical fertilizer and chemical pesticide (F <sub>4</sub> )	7.22 a	12.88 a	18.43 a
CV (%)	7.00	8.02	11.16

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

### 4.2.3 Length of the largest leaf (cm)

Significant variation was observed for leaf length of the largest leaf plant<sup>-1</sup> at different days after transplanting (DAT) due to the application of different chemical and fertilizer applications. It was found that the highest (6.77, 13.67, 22.26 and 30.19 cm) leaf length of the largest leaf plant<sup>-1</sup> was obtained in the treatment where chemical fertilizer and chemical pesticide (F<sub>4</sub>) was applied at 15, 30, 45 and 60 DAT respectively at all growth stages of cabbage varieties. On the other hand, the lowest (5.36, 9.59, 14.19 and 19.70 cm) leaf length of the largest leaf plant<sup>-1</sup> was obtained in the treatment where no

fertilizer, no manure and no pesticide (F<sub>1</sub>) was applied at 15, 30, 45 and 60 DAT respectively (Table 9). The results obtained under the present experiment was supported by Souza *et al.* (2008).

**Table 9: Main effect of fertilizer & manure applications on length of the largest leaf (cm) of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Length of the largest leaf (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	5.36 c	9.59 c	14.19 b	19.70 c
Cow dung and bio-pesticide (F <sub>2</sub> )	5.76 bc	11.35 b	15.94 b	23.47 b
Poultry and bio-pesticide (F <sub>3</sub> )	6.36 ab	12.16 b	20.78 a	25.36 b
Chemical fertilizer and chemical pesticide (F <sub>4</sub> )	6.77 a	13.67 a	22.26 a	30.19 a
CV (%)	10.67	12.12	13.91	12.39

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.2.4 Breadth of the largest leaf (cm)

Leaf breadth of the largest leaf plant<sup>-1</sup> was significantly varied with different types of fertilizer and manure applications for growth and development of cabbage varieties at different days after transplanting (DAT). It was measured that the highest (5.43, 11.47, 15.50 and 23.73 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was obtained in the treatment where chemical fertilizer and chemical pesticide (F<sub>4</sub>) was applied at 15, 30, 45 and 60 DAT respectively. On the other hand, the lowest (4.13, 7.08, 9.29 and 16.70 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was obtained in the treatment where no fertilizer, no manure and no pesticide (F<sub>1</sub>) was applied at 15, 30, 45 and 60 DAT respectively (Table 10). The results obtained under the present experiment was supported by Souza *et al.* (2008).

**Table 10: Main effect of fertilizer & manure applications on breadth of the largest (cm) leaf of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Breadth of the largest leaf (cm)			
	15 DAT	30 DAT	45 DAT	60 DAT
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	4.13 b	7.08 d	9.29 c	16.70 c
Cow dung and bio-pesticide (F <sub>2</sub> )	4.37 b	8.60 c	10.96 b	18.98 c
Poultry and bio-pesticide (F <sub>3</sub> )	5.05 a	10.17 b	14.74 a	21.41 b
Chemical fertilizer and chemical pesticide (F <sub>4</sub> )	5.43 a	11.47 a	15.50 a	23.73 a
CV (%)	13.23	13.41	12.93	11.58

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.2.5 Length of root (cm)

Fertilizer and manure applications effects on root length was significant under the present study. It is evident that different types of fertilizer and manure applications showed different root length (Table 11). The highest (16.82 cm) root length was obtained with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide) which was statistically identical with F<sub>3</sub> (poultry and bio-pesticide) and F<sub>2</sub> (cow dung and bio-pesticide). On the other hand, the lowest (13.86 cm) root length was found with the treatment of F<sub>1</sub> (no fertilizer, no manure and no pesticide). The results obtained under the present experiment was in agreement with Souza *et al.* (2008).

**Table 11: Main effect of fertilizer & manure applications on length of root, length of stem and size of the head of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Length of root(cm)	Length of stem (cm)	Size of the head (cm)
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	13.86 b	3.33 b	92.39 d
Cow dung and bio-pesticide (F <sub>2</sub> )	14.38 ab	3.55ab	106.80 c
Poultry and bio-pesticide(F <sub>3</sub> )	14.93 ab	3.65a	121.10 b
Chemical fertilizer and chemical pesticide(F <sub>4</sub> )	16.82 a	3.80a	134.60 a
CV (%)	15.73	7.59	4.90

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.2.6 Length of stem (cm)

Fertilizer and manure effect on stem length was significant under the present study. It is evident that different types of fertilizer and manure treatments showed different stem length (Table 11). The highest (3.80 cm) stem length was obtained with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide) which was statistically identical with the treatment of F<sub>3</sub> (poultry and bio-pesticide) and F<sub>2</sub> (cow dung and bio-pesticide). On the other hand, the lowest (3.33 cm) stem length was found with the treatment of F<sub>1</sub> (no fertilizer, no manure and no pesticide). Data of stem length under the present study was in agreement with Souza *et al.* (2008).

#### 4.2.7 Size of the head (cm)

Different types of fertilizer and manure applications effects on size of head was significant under the present study. It is evident that different types of fertilizer and manure treatments showed different size of head (Table 11). The highest (134.60 cm) size of head was obtained with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (92.39 cm) size of head was found with F<sub>1</sub> (no fertilizer, no manure and no pesticide).

#### 4.2.8 Weight per plant (g)

It was observed from the Table 12 that different fertilizer & manure applications treatment showed significant effect on weight of plant. Among four treatments the maximum (1967.00 g) weight of plant was recorded in the treatment where chemical fertilizer and chemical pesticide (F<sub>4</sub>) was applied whereas minimum (1065.00 g) weight of plant was recorded from the treatment where no fertilizer, no manure and no pesticide (F<sub>1</sub>) was applied.

**Table 12: Main effect of fertilizer & manure applications on weight per plant (g), weight of plant (ton ha<sup>-1</sup>) and yield of head (g) of cabbage at different DAT**

Treatments (Fertilizer & manure applications)	Weight per plant (g)	Weight of plant (ton ha <sup>-1</sup> )	Yield of head (g)
No fertilizer, no manure and no pesticide (F <sub>1</sub> )	1065.00c	53.06 c	665.80 d
Cow dung and bio-pesticide (F <sub>2</sub> )	1218.00c	60.49 c	775.30 c
Poultry and bio-pesticide(F <sub>3</sub> )	1671.00b	85.11 b	974.60b
Chemical fertilizer and chemical pesticide (F <sub>4</sub> )	1967.00a	98.22 a	1125.0a
CV (%)	13.42	12.61	9.70

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.2.9 Weight of plant (ton ha<sup>-1</sup>)

The weight of cabbage (ton ha<sup>-1</sup>) was significantly affected by the different treatments (Table 12). Among four treatments the maximum (98.22 ton ha<sup>-1</sup>) weight of plant was recorded in the treatment where chemical fertilizer and chemical pesticide (F<sub>4</sub>) was applied whereas minimum (53.06 ton ha<sup>-1</sup>) weight of plant was recorded from the treatment where no fertilizer, no manure and no pesticide (F<sub>1</sub>) was applied.

#### 4.2.10 Yield of head (g)

The result showed that yield of head was significantly affected by the different fertilizer and manure applications (Table 12). The highest (1125.00 g) yield of head was recorded in the treatment where chemical fertilizer and chemical pesticide (F<sub>4</sub>) was applied

whereas lowest (665.80 g) yield of head was recorded from the treatment where no fertilizer, no manure and no pesticide ( $F_1$ ) was applied.

#### 4.2.11 Yield of head ( $\text{ton ha}^{-1}$ )

The yield of head ( $\text{ton ha}^{-1}$ ) was significantly affected by the different fertilizer and manure applications (Fig. 2). The figure showed that highest ( $57.08 \text{ ton ha}^{-1}$ ) yield of head was recorded in the treatment where chemical fertilizer and chemical pesticide ( $F_4$ ) was applied whereas lowest ( $33.45 \text{ ton ha}^{-1}$ ) yield of head was recorded from the treatment where no fertilizer, no manure and no pesticide ( $F_1$ ) was applied.

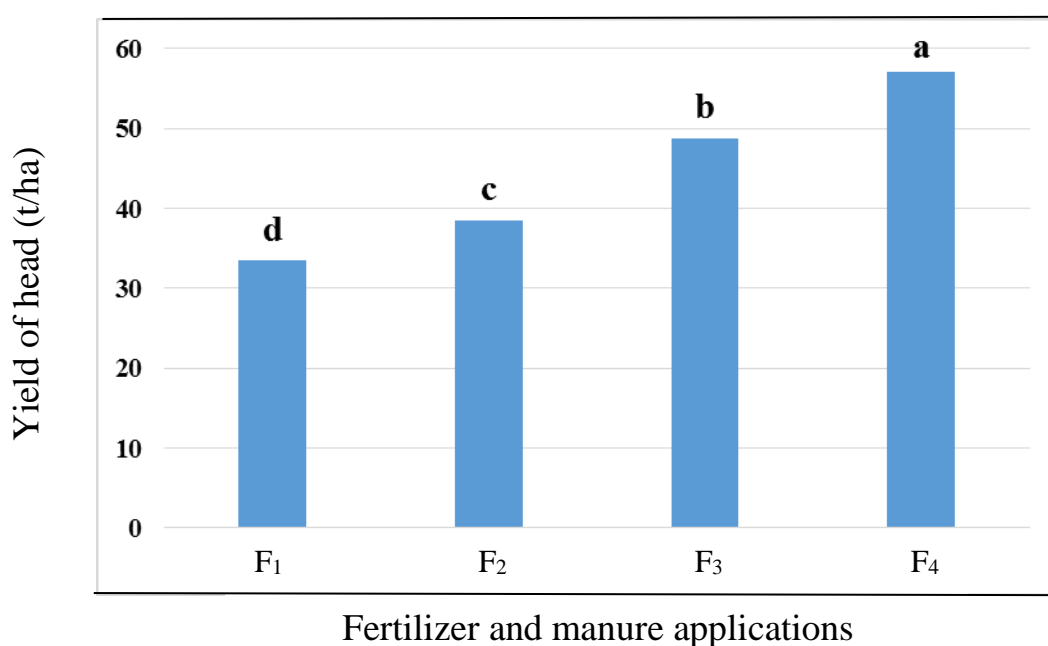


Fig. 2. Yield of head ( $\text{ton ha}^{-1}$ ) influenced by different fertilizer and manure applications

### 4.3 Interaction effect of variety and fertilizer and manure applications on growth, yield contributing characters and yield of Cabbage

#### 4.3.1 Plant height (cm)

Interaction effect of variety and different fertilizer and manure application affected plant height significantly (Table 13). At 15 DAT, the highest (13.40 cm) plant height of cabbage was recorded in the treatment combination  $V_2F_4$  (Succession Taki + recommended chemical fertilizer and chemical pesticide) which was significantly followed by the treatment combination  $V_1F_4$  (75 Cabbage + recommended chemical fertilizer and chemical pesticide),  $V_1F_3$  (75 Cabbage + poultry and bio-pesticide) and

V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (9.28 cm) plant height was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). In case of 30 DAT, the highest (22.74 cm) plant height of cabbage was recorded in the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (12.21 cm) plant height was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). At 45 DAT, the highest (27.97 cm) plant height of cabbage was recorded in the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (13.52 cm) plant height was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). Finally, at 60 and 75 DAT, the highest (41.25 and 46.53 cm) plant height of cabbage was recorded in the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) and the lowest (18.88 and 27.72 cm) plant height was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

**Table 13: Interaction effect of variety and fertilizer and manure applications on plant height (cm) of cabbage at different DAT**

Treatment combinations	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
V <sub>1</sub> F <sub>1</sub>	10.52def	17.76 cd	19.18 de	25.75 de	36.33 bcd
V <sub>1</sub> F <sub>2</sub>	11.34 bcde	20.02 abcd	23.17 bcd	31.20 bcd	37.66 bc
V <sub>1</sub> F <sub>3</sub>	12.28 abc	20.88 abc	26.50 ab	36.81 ab	40.42 b
V <sub>1</sub> F <sub>4</sub>	12.64 ab	22.74 a	27.97 a	40.95 a	45.61 a
V <sub>2</sub> F <sub>1</sub>	9.280 f	12.71 e	13.52 f	18.88 e	27.72 e
V <sub>2</sub> F <sub>2</sub>	10.00 ef	16.20 de	17.97 e	23.79 de	32.27 de
V <sub>2</sub> F <sub>3</sub>	10.32 def	17.03 cd	21.55 cde	24.44 de	34.48 cd
V <sub>2</sub> F <sub>4</sub>	13.40 a	20.62 abc	24.70 abc	28.30 cd	35.20 bcd
V <sub>3</sub> F <sub>1</sub>	11.04 cde	17.36 cd	20.16 de	30.82 bcd	34.86 cd
V <sub>3</sub> F <sub>2</sub>	11.45 bcde	18.23 bcd	21.84cde	30.86 bcd	37.95 bc
V <sub>3</sub> F <sub>3</sub>	11.70bcd	20.51 abc	25.72 abc	35.48 abc	40.17 b
V <sub>3</sub> F <sub>4</sub>	12.11 abc	21.85 ab	27.89 a	41.25 a	46.53 a
CV (%)	7.24	11.12	10.73	13.99	7.41

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.3.2 Number of leaves plant<sup>-1</sup>

Different treatment combination viewed different number of leaves plant<sup>-1</sup> according to the treatment at different days after transplanting (Table 14). In case of, 15 DAT, the highest (7.43) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) which was significantly followed by the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide), V<sub>2</sub>F<sub>2</sub> (Succession Taki + cow dung and bio-pesticide), V<sub>2</sub>F<sub>3</sub> (Succession Taki + poultry and bio-pesticide), V<sub>3</sub>F<sub>3</sub> (Succession Japani + poultry and bio-pesticide), V<sub>1</sub>F<sub>2</sub> (75 Cabbage + cow dung and bio-pesticide), V<sub>1</sub>F<sub>2</sub> (75 Cabbage + cow dung and bio-pesticide) and V<sub>2</sub>F<sub>3</sub> (Succession Taki + poultry and bio-pesticide). On the other hand, the lowest (6.13) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). At 30 DAT, the highest (13.27) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) and the lowest (10.77) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). Again at 45 DAT, the highest (20.90) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) and the lowest (13.70) number of leaves plant<sup>-1</sup> of cabbage was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).



**Table 14: Interaction effect of variety and fertilizer and manure applications on number of leaves of cabbage at different DAT**

Treatment combinations	Number of leaves plant <sup>-1</sup>		
	15 DAT	30DAT	45 DAT
V <sub>1</sub> F <sub>1</sub>	6.30 bc	11.27 bc	14.43 cd
V <sub>1</sub> F <sub>2</sub>	6.83abc	11.27 bc	14.53 cd
V <sub>1</sub> F <sub>3</sub>	7.03abc	12.27 abc	16.00 bcd
V <sub>1</sub> F <sub>4</sub>	7.10 ab	12.53 abc	17.53 bc
V <sub>2</sub> F <sub>1</sub>	6.60abc	11.80 abc	13.70 d
V <sub>2</sub> F <sub>2</sub>	6.80abc	12.30 abc	15.73 bcd
V <sub>2</sub> F <sub>3</sub>	6.93abc	13.23 a	19.00 ab
V <sub>2</sub> F <sub>4</sub>	7.43 a	13.27 a	20.90 a
V <sub>3</sub> F <sub>1</sub>	6.13 c	10.77 c	14.70 cd
V <sub>3</sub> F <sub>2</sub>	6.23 bc	11.71 abc	16.50 bcd
V <sub>3</sub> F <sub>3</sub>	6.90abc	12.53 abc	16.60 bcd
V <sub>3</sub> F <sub>4</sub>	7.13 ab	12.83 ab	16.87 bcd
CV (%)	7.00	8.02	11.16

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.3.3 Length of the largest leaf (cm)

Leaf length plant<sup>-1</sup> with petiole varied significantly with interaction effect of variety and different type fertilizer and manure applications (Table 15). Different treatment combination viewed different leaf length per plant at different days after transplanting (DAT). In case of 15 DAT, it was observed that highest (7.05) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki +

recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>3</sub>F<sub>3</sub> (Succession Japani + poultry and bio-pesticide), V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide), V<sub>2</sub>F<sub>3</sub> (Succession Taki + poultry and bio-pesticide) and V<sub>1</sub>F<sub>2</sub> (75 Cabbage + cow dung and bio-pesticide). On the other hand, the lowest (5.37) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). At 30 DAT, the highest (14.62) leaf length of the largest leaf plant<sup>-1</sup> was achieved with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (9.17) leaf length of the largest leaf plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). Again at 45 DAT, the highest (24.44) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and lowest (10.65) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). Finally at 60 DAT, the highest (33.48) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) and lowest (14.15) leaf length of the largest leaf plant<sup>-1</sup> was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

**Table 15: Interaction effect of variety and fertilizer and manure applications on length of the largest leaf of cabbage at different DAT**

Treatment combinations	Length of the largest leaf (cm)			
	15 DAT	30DAT	45 DAT	60 DAT
V <sub>1</sub> F <sub>1</sub>	5.46 c	10.19 cde	16.11 bc	23.13 cdef
V <sub>1</sub> F <sub>2</sub>	5.88abc	11.85 bcde	17.28 bc	26.56 cd
V <sub>1</sub> F <sub>3</sub>	6.28abc	12.11 abcd	22.96 a	28.24 abc
V <sub>1</sub> F <sub>4</sub>	6.50abc	14.62 a	24.44 a	32.85 ab
V <sub>2</sub> F <sub>1</sub>	5.37 c	9.17 e	10.65 d	14.15 g
V <sub>2</sub> F <sub>2</sub>	5.74 bc	10.72 cde	14.48 cd	18.14 fg
V <sub>2</sub> F <sub>3</sub>	6.04abc	11.86 bcde	17.41bc	20.04 ef
V <sub>2</sub> F <sub>4</sub>	7.05 a	13.51 ab	19.79 ab	24.25 cde
V <sub>3</sub> F <sub>1</sub>	5.27 c	9.41 de	15.80 bc	21.82 def
V <sub>3</sub> F <sub>2</sub>	5.67 bc	11.48 bcde	16.05 bc	25.69 cde
V <sub>3</sub> F <sub>3</sub>	6.75 ab	12.53 abc	21.97 a	27.80 bc
V <sub>3</sub> F <sub>4</sub>	6.76 ab	12.87 abc	22.55 a	33.48 a
CV (%)	10.67	12.12	13.91	12.39

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.3.4 Breadth of the largest leaf (cm)

Significant variation was observed in of leaf breadth plant<sup>-1</sup> with interaction effect of variety and different type fertilizer and manure applications (Table 16). Different treatment combination viewed different leaf breadth plant<sup>-1</sup> at different days after

transplanting (DAT). In case of 15 DAT, it was observed that the highest (5.86 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>3</sub>F<sub>3</sub> (Succession Japani + poultry and bio-pesticide), V<sub>2</sub>F<sub>3</sub> (Succession Taki + poultry and bio-pesticide), V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide) and V<sub>2</sub>F<sub>2</sub> (Succession Taki + cow dung and bio-pesticide). On the other hand, the lowest (3.88 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). At 30 DAT, the highest (12.23 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (6.89 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). Again 45 DAT, the highest (15.77 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) and the lowest (8.29 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). Finally at 60 DAT, the highest (26.04 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) and the lowest (14.45 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

**Table 16: Interaction effect of variety and fertilizer and manure applications on breadth of the largest leaf (cm) of cabbage at different DAT**

Treatment combinations	Breadth of the largest leaf (cm)			
	15 DAT	30DAT	45 DAT	60 DAT
V <sub>1</sub> F <sub>1</sub>	4.07 cd	7.18 de	9.563 b	17.83 def
V <sub>1</sub> F <sub>2</sub>	4.14 cd	8.71 cde	11.36 b	21.68 bcd
V <sub>1</sub> F <sub>3</sub>	4.77abcd	9.52bcd	14.60 a	23.15 abc
V <sub>1</sub> F <sub>4</sub>	5.07abcd	12.23 a	15.55 a	24.85 ab
V <sub>2</sub> F <sub>1</sub>	4.44 bcd	7.15 de	8.29 b	14.45 f
V <sub>2</sub> F <sub>2</sub>	4.70abcd	8.39 cde	10.49 b	16.40 ef
V <sub>2</sub> F <sub>3</sub>	5.16abc	11.21 ab	15.45 a	20.22 cde
V <sub>2</sub> F <sub>4</sub>	5.86 a	11.64 ab	15.77 a	20.29 cde
V <sub>3</sub> F <sub>1</sub>	3.88 d	6.89 e	10.03 b	17.82 def
V <sub>3</sub> F <sub>2</sub>	4.26 bcd	8.71 cde	11.03 b	18.86 cde
V <sub>3</sub> F <sub>3</sub>	5.21abc	9.78bc	14.17 a	20.85 bcde
V <sub>3</sub> F <sub>4</sub>	5.36 ab	10.53abc	15.20 a	26.04 a
CV (%)	13.23	13.41	12.93	11.58

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.3.5 Length of root (cm)

Interaction effect of different variety and different types of fertilizer and manure applications had significant effect on root length. Different treatment combination showed different root length (Table 17). The highest (19.67 cm) root length was observed with the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) which was significantly followed by the treatment combination V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide), V<sub>1</sub>F<sub>2</sub> (75 Cabbage + cow

dung and bio-pesticide), V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>1</sub> (75 Cabbage + no fertilizer, no manure and no pesticide), V<sub>3</sub>F<sub>3</sub> (Succession Japani + poultry and bio-pesticide) and V<sub>3</sub>F<sub>2</sub> (Succession Japani + cow dung and bio-pesticide). On the other hand, the lowest (11.19 cm) root length per plant was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

**Table 17: Interaction effect of variety and fertilizer and manure applications on length of root (cm), length of stem (cm) and size of head (cm) of cabbage at different DAT**

Treatment combinations	Length of root (cm)	Length of stem (cm)	Size of the head (cm)
V <sub>1</sub> F <sub>1</sub>	16.27 ab	3.35 bc	94.68 f
V <sub>1</sub> F <sub>2</sub>	16.67 ab	3.62abc	104.70 e
V <sub>1</sub> F <sub>3</sub>	16.83 ab	3.68abc	115.10 cd
V <sub>1</sub> F <sub>4</sub>	19.67 a	3.94 a	138.10 a
V <sub>2</sub> F <sub>1</sub>	11.19 c	3.16 c	93.47 f
V <sub>2</sub> F <sub>2</sub>	11.36 c	3.35 bc	105.40 de
V <sub>2</sub> F <sub>3</sub>	12.11 bc	3.59abc	123.90bc
V <sub>2</sub> F <sub>4</sub>	14.33 bc	3.64abc	126.10 b
V <sub>3</sub> F <sub>1</sub>	14.11 bc	3.49abc	89.010 f
V <sub>3</sub> F <sub>2</sub>	15.11 abc	3.69abc	110.30 de
V <sub>3</sub> F <sub>3</sub>	15.83 abc	3.69abc	124.40 bc
V <sub>3</sub> F <sub>4</sub>	16.45 ab	3.81 ab	139.60 a
CV (%)	15.73	7.59	4.90

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at  $P \leq 5\%$  level.

#### 4.3.6 Length of stem (cm)

Interaction effect of different variety and different types of fertilizer and manure applications had significant effect on stem length. Different treatment combination showed different root length (Table 17). The highest (3.94 cm) stem length was observed with the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>3</sub>F<sub>3</sub> (Succession Japani + poultry and bio-pesticide), V<sub>3</sub>F<sub>2</sub> (Succession Japani + cow dung and bio-pesticide), V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide), V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>2</sub> (75 Cabbage + cow dung and bio-pesticide), V<sub>2</sub>F<sub>3</sub> (Succession Taki + poultry and bio-pesticide) and V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). On the other hand, the lowest (3.16 cm) stem length per plant was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

#### 4.3.7 Size of the head (cm)

Interaction effect of different variety and different types of fertilizer and manure applications had significant effect on size of head (Table 17). The highest (139.60 cm) size of the head was recorded from the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (89.01 cm) size of the head was obtained from the treatment combination V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide).

#### 4.3.8 Weight per plant (g)

Weight per plant (g) was also found significantly different inclined by the variety and different types of fertilizer and manure applications (Table 18). It was observed that the highest (2250.00 g) weight per plant was achieved with the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-pesticide). On the other hand, the lowest (808.30 g) weight per plant was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

**Table 18: Interaction effect of variety and fertilizer and manure applications on weight per plant (g), weight of plant (ton ha<sup>-1</sup>) and yield of head (g) of cabbage at different DAT**

Treatment Combinations	Weight per plant (g)	Weight of plant (ton ha <sup>-1</sup> )	Yield of head (g)
V <sub>1</sub> F <sub>1</sub>	1173.00 e	57.44 d	697.30 d
V <sub>1</sub> F <sub>2</sub>	1207.00 de	60.13 d	783.30 d
V <sub>1</sub> F <sub>3</sub>	1903.00abc	95.89 ab	1072.00 b
V <sub>1</sub> F <sub>4</sub>	2080.00 ab	103.00 a	1112.00 b
V <sub>2</sub> F <sub>1</sub>	808.30 f	40.50 e	541.30 e
V <sub>2</sub> F <sub>2</sub>	1147.00 e	57.00 d	772.70 d
V <sub>2</sub> F <sub>3</sub>	1267.00 de	65.89 cd	854.70 cd
V <sub>2</sub> F <sub>4</sub>	1570.00 cd	81.56 bc	1001.00 bc
V <sub>3</sub> F <sub>1</sub>	1213.00 de	61.22 d	758.70 d
V <sub>3</sub> F <sub>2</sub>	1300.00 de	64.33 d	770.00 d
V <sub>3</sub> F <sub>3</sub>	1843.00 bc	93.56 ab	996.70bc
V <sub>3</sub> F <sub>4</sub>	2250.00 a	110.10 a	1263.00 a
CV (%)	13.42	12.61	9.70

V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>=Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide and V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly by DMRT at P ≤ 5% level.

#### 4.3.9 Weight of plant (ton ha<sup>-1</sup>)

Weight per plant (ton ha<sup>-1</sup>) was also found significantly different inclined by the variety and different types of fertilizer and manure applications (Table 18). It was observed that the highest weight (103.00 ton ha<sup>-1</sup>) per plant was achieved with the treatment combination V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) which was significantly followed by V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide), V<sub>1</sub>F<sub>3</sub> (75 Cabbage + poultry and bio-



pesticide) and V<sub>3</sub>F<sub>3</sub> (Succession Japan + poultry and bio-pesticide). On the other hand, the lowest weight (40.50 ton ha<sup>-1</sup>) per plant was achieved with the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

#### 4.3.10 Yield of head (g)

The yield of head (g) was significantly affected by the variety and different types of fertilizer and manure applications (Table 18). The highest (1263.00 g) yield of head was recorded in the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japan + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (541.30 g) yield of head was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

#### 4.3.11 Yield of head (ton ha<sup>-1</sup>)

The yield of head (ton ha<sup>-1</sup>) was significantly affected by variety and different types of fertilizer and manure applications (Fig. 3). The highest (63.85 ton ha<sup>-1</sup>) yield of head was recorded in the treatment combination V<sub>3</sub>F<sub>4</sub> (Succession Japan + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (27.68 ton ha<sup>-1</sup>) yield of head was recorded in the treatment combination V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

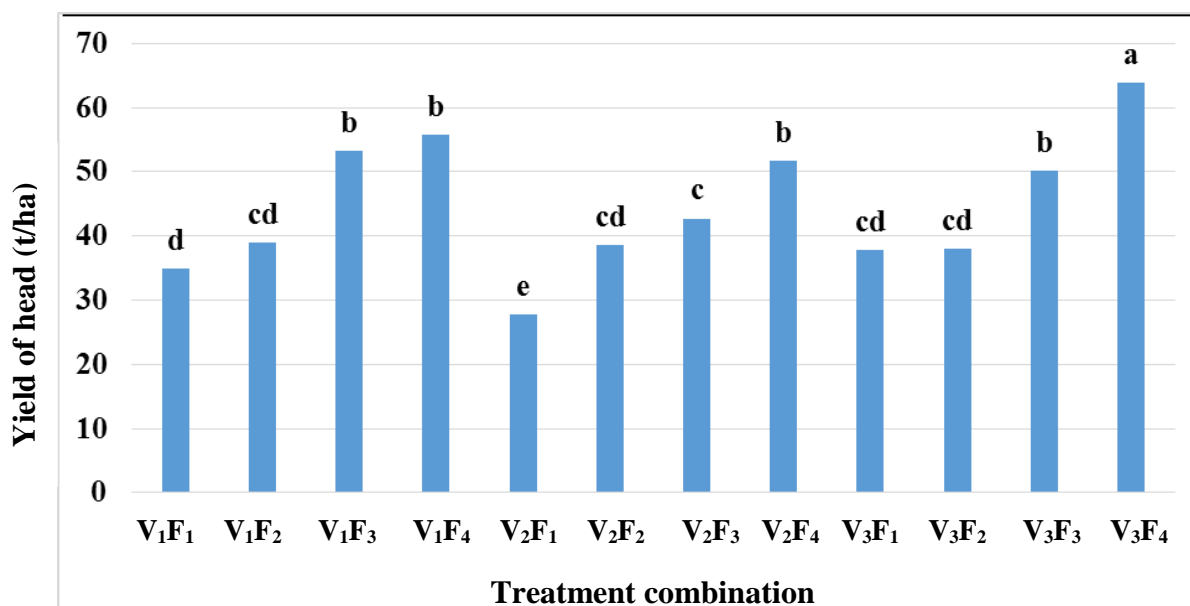


Fig. 3. Yield of head (ton ha<sup>-1</sup>) influenced by Interaction effect of variety and fertilizer and manure applications

#### 4.4 Economic analysis

Profitability of growing potato as inter-crop in mango based Agroforestry system was calculated based on local market rate prevailed during experiment. The cost of production of cabbage and cost of production of tree plantation and management of trees have been summarized appendix III. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 19.

##### 4.4.1 Total cost of production

The values in Table 19 indicate that the total cost of production was maximum 167279 tk ha<sup>-1</sup> in Mango + cabbage based agroforestry system where chemical fertilizer was applied (V<sub>3</sub>F<sub>4</sub>). Whereas the minimum cost of production 144893 tk ha<sup>-1</sup> was recorded from the sole cropping of cabbage where no fertilizer was applied (V<sub>2</sub>F<sub>1</sub>).

##### 4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. The values in table 19 indicate that the highest value of gross return 789100 tk ha<sup>-1</sup> was obtained from Mango + cabbage based agroforestry system where chemical fertilizer was applied (V<sub>3</sub>F<sub>4</sub>). On the other hand, the lowest value of gross return 427400 tk ha<sup>-1</sup> was obtained from sole cropping of cabbage where no fertilizer was applied (V<sub>2</sub>F<sub>1</sub>).

##### 4.4.3 Net return

Results presented in the Table 19 show that net return 621821 tk ha<sup>-1</sup> was comparatively higher in producing cabbage under Mango + cabbage based agroforestry system where chemical fertilizer was applied (V<sub>3</sub>F<sub>4</sub>). At the same time, the lowest net return 282507 tk ha<sup>-1</sup> was obtained from sole cropping of cabbage where no fertilizer was applied (V<sub>2</sub>F<sub>1</sub>). Higher net return was the result of higher gross return from the cabbage cultivation together with mango trees.

##### 4.4.4 Benefit-cost ratio (BCR)

The values in Table 19 indicate that the highest (4.72) benefit-cost ratio was recorded from variety Succession Japani+ mango based agroforestry system where chemical fertilizer and chemical pesticide was applied (V<sub>3</sub>F<sub>4</sub>). On the other hand, the lowest (2.95) benefit-cost ratio was obtained from variety Succession Taki+ mango based agroforestry

system where no fertilizer, no manure and no pesticide was applied (V<sub>2</sub>F<sub>1</sub>). So, cabbage can profitably be cultivated in mango based agroforestry system.

**Table 19: Economic Analysis of Cabbage production under Mango based Agroforestry system (ha<sup>-1</sup>year<sup>-1</sup>)**

Treatment combinations	Return (tk ha <sup>-1</sup> )		Gross Return (tk ha <sup>-1</sup> )	Total cost of production (tk ha <sup>-1</sup> )	Net Return	BCR
	Mango	Cabbage				
V <sub>1</sub> F <sub>1</sub>	150600	348900	499500	146927	352573	3.40
V <sub>1</sub> F <sub>2</sub>	150600	390400	541000	155210	385790	3.49
V <sub>1</sub> F <sub>3</sub>	150600	533200	683800	152702	531098	4.48
V <sub>1</sub> F <sub>4</sub>	150600	557100	707700	164702	542998	4.30
V <sub>2</sub> F <sub>1</sub>	150600	276800	427400	144893	282507	2.95
V <sub>2</sub> F <sub>2</sub>	150600	385300	535900	153176	382724	3.50
V <sub>2</sub> F <sub>3</sub>	150600	427200	577800	150668	427132	3.83
V <sub>2</sub> F <sub>4</sub>	150600	516800	667400	162668	504732	4.10
V <sub>3</sub> F <sub>1</sub>	150600	377800	528400	149504	378896	3.53
V <sub>3</sub> F <sub>2</sub>	150600	379700	530300	157787	372513	3.36
V <sub>3</sub> F <sub>3</sub>	150600	502100	652700	155278	497422	4.20
V <sub>3</sub> F <sub>4</sub>	150600	638500	789100	167279	621821	4.72

Note: Cabbage 10tk/kg, Mango fruit 1600 tk / Tree /Year

## CHAPTER 5

### SUMMARY, CONCLUSION AND RECOMMENDATIONS

#### 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 2016 to March 2017 to evaluate the potentiality of organic cabbage production under mango based agroforestry system. The experiment was conducted in newly established mango orchard where the tree saplings were planted at the spacing 6 m × 6 m in the year 2006. The experiment was laid out in two factorial RCBD with 3 (three) replications. Factor A (Three cabbage variety) viz.  $V_1 = 75$  Cabbage,  $V_2 =$  Succession Taki and  $V_3 =$  Succession Japani. Factor B (Four fertilizer & manure applications) viz.  $F_1 =$  no fertilizer, manure and pesticide,  $F_2 =$  cow dung and bio-pesticide,  $F_3 =$  poultry and bio-pesticide and  $F_4 =$  recommended chemical fertilizer and chemical pesticide. So, the treatment combinations of the experiment were:  $V_1F_1=$  75 Cabbage + no fertilizer, manure and pesticide,  $V_1F_2=$  75 Cabbage + cow dung and bio-pesticide,  $V_1F_3=$  75 Cabbage + poultry and bio-pesticide,  $V_1F_4=$  75 Cabbage + recommended chemical fertilizer and chemical pesticide,  $V_2F_1=$  Succession Taki + no fertilizer, manure and pesticide,  $V_2F_2=$  Succession Taki + cow dung and bio-pesticide,  $V_2F_3=$  Succession Taki + poultry and bio-pesticide,  $V_2F_4=$  Succession Taki + recommended chemical fertilizer and chemical pesticide,  $V_3F_1=$  Succession Japani + no fertilizer, manure and pesticide,  $V_3F_2=$  Succession Japani + cow dung and bio-pesticide,  $V_3F_3=$  Succession Japani + poultry and bio-pesticide and  $V_3F_4=$  Succession Japani + recommended chemical fertilizer and chemical pesticide.

The land of experimental plot was opened in the last week of November 2016 with a power tiller and it was made ready for planting on 08<sup>th</sup> December 2016. Transplanting was done late afternoon on 08<sup>th</sup> December 2016. Cabbage seedlings were 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 cabbage, the results were found that the plant height, number of leaves plant<sup>-1</sup>, leaf length, leaf breadth, root length, stem length, size of head and yield were significantly different. The tallest plant height (11.70, 20.35, 24.20, 40.01 cm) at 15, 30, 45, 75 DAT was recorded from the variety 75 Cabbage (V<sub>1</sub>). At 60 DAT tallest plant height (34.60 cm) was recorded from the variety Succession Japani (V<sub>3</sub>). On the other hand, shortest plant height (10.75, 16.64, 19.44, 23.85 and 32.42 cm) at 15, 30, 45, 60 and 75 DAT was recorded from the variety Succession Taki (V<sub>2</sub>). Leaf length of cabbage was also varied due to different varietal effects. The highest (6.94, 12.65 and 17.33 respectively) number of leaves plant<sup>-1</sup> at 15, 30 and 45 DAT was recorded with variety Succession Taki (V<sub>2</sub>). On the contrary, the lowest (11.83 and 15.63 respectively) number of leaves plant<sup>-1</sup> at 30 and 45 DAT was obtained with variety 75 Cabbage (V<sub>1</sub>). Leaf length plant<sup>-1</sup> was significantly influenced by different cabbage varieties. At 15 DAT, the highest (6.11 cm) leaf length was recorded from the variety Succession Japani (V<sub>3</sub>) and the lowest (6.03 cm) leaf length was recorded from variety 75 Cabbage (V<sub>1</sub>). At 30, 45 and 60 DAT the highest (12.19, 20.20 and 27.69 cm) length of the largest leaf was recorded from variety 75 Cabbage (V<sub>1</sub>) whereas the lowest (11.32, 15.58 and 19.14 cm) length of the largest leaf was recorded from variety Succession Taki (V<sub>2</sub>). Cabbage leaf breadth was also influenced due to their varietal characters. At 15 DAT, the highest (5.04 cm) leaf breadth was recorded from the variety Succession Taki (V<sub>2</sub>) whereas the minimum (4.51 cm) breadth of leaf was observed from variety 75 Cabbage (V<sub>1</sub>). At 30 DAT, the highest (9.60 cm) leaf breadth was recorded from the variety Succession Taki (V<sub>2</sub>) whereas the minimum (8.98 cm) breadth of leaf was observed from variety Succession Japani (V<sub>3</sub>). Similar trend of increasing breadth of the largest leaf was observed at 45 and 60 DAT, the widest leaf (12.77 cm and 21.88 cm) was recorded from the variety 75 Cabbage (V<sub>1</sub>). On the other hand, the lowest (12.50 cm and 17.84 cm) breadth of leaf was recorded with variety Succession Taki (V<sub>2</sub>). Different varieties showed different root length and it was measured at the time of harvest. It was observed that, variety 75 Cabbage (V<sub>1</sub>) verified the highest (17.36 cm) root length at harvest and the lowest (12.25 cm) root length among the varieties was obtained with variety Succession Taki (V<sub>2</sub>) at harvest. Different varieties showed different stem length and it was deliberate at the time of harvest. It was observed that variety Succession Japani (V<sub>3</sub>) verified the highest (3.67 cm) stem length at harvest and the lowest (3.43 cm) stem

length among the varieties was obtained variety Succession Taki ( $V_2$ ) at harvest. Size of the head was affected significantly by the different shade levels. The highest (115.80 cm) size of the head was recorded from variety Succession Japan ( $V_3$ ) at harvest and the lowest (112.20 cm) size of the head among the varieties was obtained from variety Succession Taki ( $V_2$ ) at harvest. The highest (1652.00 g) weight of plant was recorded in variety Succession Japan ( $V_3$ ) and the lowest (1198.00 g) weight of plant was recorded from variety Succession Taki ( $V_2$ ). The highest (82.31 ton ha<sup>-1</sup>) weight of plant was recorded in variety Succession Japan ( $V_3$ ) and the lowest (61.24 ton ha<sup>-1</sup>) weight of plant was recorded from variety Succession Taki ( $V_2$ ). The highest (947.00 g) yield of head was recorded in variety Succession Japan ( $V_3$ ) and the lowest (792.40 g) yield of head was recorded from variety Succession Taki ( $V_2$ ). The highest (47.45 ton ha<sup>-1</sup>) yield of head was recorded in variety Succession Japan ( $V_3$ ) the lowest (40.15 ton ha<sup>-1</sup>) yield of head was recorded from variety Succession Taki ( $V_2$ ). However, the suitability of variety will be as variety Succession Japan > 75 Cabbage > Succession Taki.

Again, the result of the research were showed that the main effect of fertilizer and manure were significant in respect of plant height, number of leaves per plant, leaf length, leaf breadth, root length, stem length, size of head and yield were significantly different. Plant height was significantly affected by different fertilizer and manure applications. The highest (12.72, 21.74, 26.85, 36.83 and 42.45 cm) plant height at 15, 30, 45, 60 and 75 DAT respectively was obtained with chemical fertilizer and chemical pesticide ( $F_4$ ). On the other hand, the lowest (10.28, 15.95, 17.62, 25.15 and 32.97 cm) plant height at 15, 30, 45, 60 and 75 DAT respectively was recorded with no fertilizer, no manure and no pesticide ( $F_1$ ). The highest (7.22, 12.88 and 18.43) number of leaves plant<sup>-1</sup> at 15, 30 and 45 DAT respectively was obtained with chemical fertilizer and chemical pesticide ( $F_4$ ). The lowest (6.34, 11.28 and 14.28) number of leaves plant<sup>-1</sup> was found respectively with no fertilizer, manure and pesticide ( $F_1$ ). It was considered that the highest (6.77, 13.67, 22.26 and 30.19 cm) leaf length of the largest leaf plant<sup>-1</sup> at 15, 30, 45 and 60 DAT respectively at all growth stages of cabbage was obtained with chemical fertilizer and chemical pesticide ( $F_4$ ). The lowest (5.36, 9.59, 14.19 and 19.70 cm) leaf length of the largest leaf plant<sup>-1</sup> at 15, 30, 45 and 60 DAT respectively was obtained with no fertilizer, no manure and no pesticide ( $F_1$ ). The highest (5.43, 11.47, 15.50 and 23.73 cm) leaf breadth of the largest leaf plant<sup>-1</sup> at 15, 30, 45 and 60 DAT respectively was obtained with chemical fertilizer and chemical pesticide ( $F_4$ ). On the

other hand, the lowest (4.13, 7.08, 9.29 and 16.70 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was found with no fertilizer, no manure and no pesticide (F<sub>1</sub>). It is evident that different types of fertilizer and manure applications showed different root length. The highest (16.82 cm) root length was observed with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (13.86 cm) root length was found with F<sub>1</sub> (no fertilizer, no manure and no pesticide). The highest (3.80 cm) stem length was observed with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (3.33 cm) stem length was found with F<sub>1</sub> (no fertilizer, no manure and no pesticide).

It is observed that different types of fertilizer and manure applications showed different size of head. The highest (134.60 cm) size of head was observed with the treatment of F<sub>4</sub> (recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (92.39 cm) size of head was found with F<sub>1</sub> (no fertilizer, no manure and no pesticide). Among four treatments the maximum (1967.00 g) weight of plant was recorded in chemical fertilizer and chemical pesticide (F<sub>4</sub>) whereas minimum (1065.00 g) weight of plant was recorded from no fertilizer, no manure and no pesticide (F<sub>1</sub>). Among four treatments the maximum (98.22 ton ha<sup>-1</sup>) weight of plant was recorded in chemical fertilizer and chemical pesticide (F<sub>4</sub>) whereas minimum (53.06 ton ha<sup>-1</sup>) weight of plant was recorded from no fertilizer, no manure and no pesticide (F<sub>1</sub>). The highest (1125.00 g) yield of head was recorded in chemical fertilizer and chemical pesticide (F<sub>4</sub>) whereas the lowest (665.80 g) yield of head was recorded from no fertilizer, no manure and no pesticide (F<sub>1</sub>). The result showed that highest (57.08 ton ha<sup>-1</sup>) yield of head was recorded in chemical fertilizer and chemical pesticide (F<sub>4</sub>) whereas lowest (33.45 ton ha<sup>-1</sup>) yield of head was recorded from no fertilizer, no manure and no pesticide (F<sub>1</sub>).

Again, the interaction effect of variety and fertilizer and manure applications of cabbage had significant effect on plant height, number of leaves plant<sup>-1</sup>, leaf length, leaf breadth, root length, stem length, size of head and yield. At 15 DAT, the tallest (13.40 cm) plant height of cabbage was recorded in V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide). At 30 and 45 DAT, the tallest (22.74 and 27.97 cm) plant height of cabbage was recorded in V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide). At 60 and 75 DAT, the tallest (41.25 and 46.53 cm) plant height of cabbage was recorded in V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended

chemical fertilizer and chemical pesticide). On the other hand, the lowest (9.28, 12.21, 13.52, 18.88 and 27.72 cm) plant height was recorded in V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). Different treatment combinations showed different no. of leaves at different days after transplanting. At 15, 30 and 45 DAT, the highest (7.43, 13.27, 20.90) number of leaves plant<sup>-1</sup> of cabbage was recorded in V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (6.13, 10.77, 13.70) number of leaves plant<sup>-1</sup> of cabbage was recorded in V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). At 15 DAT, it was observed that highest (7.05 cm) leaf length of the largest leaf plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide). At 30 and 45 DAT, the highest (14.62, 24.44 cm) leaf length of the largest leaf plant<sup>-1</sup> was achieved with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide). And at 60 DAT, the highest leaf length of the largest leaf (33.48 cm) plant<sup>-1</sup> was recorded in V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (5.37, 9.17, 10.65, 14.15 cm) leaf length of the largest leaf plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

Different treatment combinations showed different leaf breadth plant<sup>-1</sup> at different days after transplanting. At 15 DAT, it was observed that the highest (5.86 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide), the lowest (3.88 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). At 30 DAT, the highest (12.23 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (6.89 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). At 45 DAT, the highest (15.77 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>4</sub> (Succession Taki + recommended chemical fertilizer and chemical pesticide) and the lowest (8.29 cm) leaf breadth plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). And at 60 DAT, the highest (26.04 cm) leaf breadth of the largest leaf plant<sup>-1</sup> was achieved with V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) and the lowest (14.45 cm) leaf breadth was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no



pesticide). Different treatment combinations showed different root length. The highest (19.67 cm) root length was observed with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (11.19 cm) root length plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). The highest (3.94 cm) stem length was observed with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide) and the lowest (3.16 cm) stem length plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). The highest size of the head was recorded from V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide) and the lowest size of the head (89.01 cm) was obtained from V<sub>3</sub>F<sub>1</sub> (Succession Japani + no fertilizer, no manure and no pesticide). It was observed that the highest (2250.00 g) weight plant<sup>-1</sup> was achieved with V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (808.30 g) weight plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

It was observed that the highest (103 ton ha<sup>-1</sup>) weight plant<sup>-1</sup> was achieved with V<sub>1</sub>F<sub>4</sub> (75 Cabbage + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (40.50 ton ha<sup>-1</sup>) weight plant<sup>-1</sup> was achieved with V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). The highest (1263.00 g) yield of head was recorded in V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (541.30 g) yield of head was recorded in V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide). The highest (63.85 ton ha<sup>-1</sup>) yield of head was recorded in V<sub>3</sub>F<sub>4</sub> (Succession Japani + recommended chemical fertilizer and chemical pesticide). On the other hand, the lowest (27.68 ton ha<sup>-1</sup>) yield of head was recorded in V<sub>2</sub>F<sub>1</sub> (Succession Taki + no fertilizer, no manure and no pesticide).

Again, in case of economic analysis, the total cost of production was maximum (167279 tk ha<sup>-1</sup>) in variety Succession Japani where chemical fertilizer was applied (V<sub>3</sub>F<sub>4</sub>) whereas minimum (144893 tk ha<sup>-1</sup>) cost of production was recorded from variety Succession Taki where no fertilizer, manure and pesticide (V<sub>2</sub>F<sub>1</sub>) was applied. The highest (789100 tk ha<sup>-1</sup>) value of gross return was obtained from cabbage variety Succession Japani where chemical fertilizer was applied (V<sub>3</sub>F<sub>4</sub>). On the other hand, the lowest (427400 tk ha<sup>-1</sup>) value of gross return was obtained from variety Succession Taki where no fertilizer, manure and pesticide (V<sub>2</sub>F<sub>1</sub>) was applied. Net return (621821 tk ha<sup>-1</sup>)

was comparatively higher in variety Succession Japani where chemical fertilizer was applied ( $V_3F_4$ ). At the same time, the lowest (282507 tk ha<sup>-1</sup>) net return was received from variety Succession Taki where no fertilizer, manure and pesticide ( $V_2F_1$ ) was applied. The highest benefit cost ratio (4.72) was recorded from variety Succession Japani where chemical fertilizer was applied ( $V_3F_4$ ) and lowest benefit cost ratio (2.95) was observed from variety Succession Taki where no fertilizer, manure and pesticide ( $V_2F_1$ ).

## 5.2 Conclusion

The findings of the present investigation indicated that diversification of farming system and growing cabbage as ground layer crops with different fertilizer and manure applications in young mango tree orchard is a viable option for more income of farmers. In case of cabbage production under mango + cabbage agroforestry system, chemical fertilizer as well as poultry + bio-pesticide may be a good practice. The presence of tree canopies did not influence so much on the growth and yield of cabbage. However, the suitability of the cultivation of different cabbage variety under mango based Agroforestry system may be ranked as Succession Japani > 75 Cabbage > Succession Taki. Finally, it may be concluded that, the application of organic manure gave less production as compared to chemical fertilizer application. But, if we consider the benefit of organic manure application in terms of environmental benefit, soil health and safe cabbage production then cultivation of cabbage variety at the floor of mango orchard with organic manure application may be a promising mango based agroforestry system in the northern part of Bangladesh.

## 5.3 Recommendations

1. Cultivation of cabbage variety Succession Japani with poultry and neem oil spray as bio-pesticide at the floor of young mango orchard is a good organic cabbage + mango based agroforestry system.
2. The present research work was carried out at the Hajee Mohammad Danesh Science and Technology University and one season only. Further trial of this work in different locations of the country using different aged mango orchard is needed to justify the result for final recommendations.

## 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 ( $\mu\text{g/g}$ )	24.0
Sulphur ( $\mu\text{g/g}$ )	3.2
Boron ( $\mu\text{g/g}$ )	0.27
Iron ( $\mu\text{g/g}$ )	5.30
Zinc ( $\mu\text{g/g}$ )	0.90

Source: Soil Resources Development Institute, Dinajpur (2017)

**Appendix-II: Weather data of the experimental site during the period from  
November 2016 to March 2017.**

Months	* Air Temperature ( $^{\circ}$ C)			* Minimum Rainfall (mm)	* Relative Humidity (%)
	Maximum	Minimum	Average		
November 2016	29.85	19.68	24.77	05.00	88.50
December 2016	28.70	18.45	23.56	18.00	85.92
January 2017	27.20	16.10	21.65	12.00	83.45
February 2017	26.95	15.78	21.37	00.00	82.20
March 2017	29.61	20.57	25.09	18.50	80.61

Note \* Monthly average

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

## Appendix- III: Production cost analysis of cabbage under mango 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)	Interest of the value of land (tk. 300000/ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the total input cost (tk/ha)	
	Mango	Cabbage	Total non-material cost	seedling	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial Plantation cost of trees	Total material cost (Tk/ha)					
V <sub>1</sub> F <sub>1</sub>	11675	38390	50065	28300	0	0	3260	6850	23850	62260	112325	8986	20000	5616	146927
V <sub>1</sub> F <sub>2</sub>	11675	38390	50065	28300	5650	1680	3260	6850	23850	69590	119655	9572	20000	5983	155210
V <sub>1</sub> F <sub>3</sub>	11675	38390	50065	28300	3250	1860	3260	6850	23850	67370	117435	9395	20000	5872	152702
V <sub>1</sub> F <sub>4</sub>	11675	38390	50065	28300	10860	4870	3260	6850	23850	77990	128055	10244	20000	6403	164702
V <sub>2</sub> F <sub>1</sub>	11675	38390	50065	26500	0	0	3260	6850	23850	60460	110525	8842	20000	5526	144893
V <sub>2</sub> F <sub>2</sub>	11675	38390	50065	26500	5650	1680	3260	6850	23850	67790	117855	9428	20000	5893	153176
V <sub>2</sub> F <sub>3</sub>	11675	38390	50065	26500	3250	1860	3260	6850	23850	65570	115635	9251	20000	5782	150668
V <sub>2</sub> V <sub>4</sub>	11675	38390	50065	26500	10860	4870	3260	6850	23850	76190	126255	10100	20000	6313	162668
V <sub>3</sub> F <sub>1</sub>	11675	38390	50065	30580	0	0	3260	6850	23850	64540	114605	9168	20000	5730	149504
V <sub>3</sub> F <sub>2</sub>	11675	38390	50065	30580	5650	1680	3260	6850	23850	71870	121935	9755	20000	6097	157787
V <sub>3</sub> F <sub>3</sub>	11675	38390	50065	30580	3250	1860	3260	6850	23850	69650	119715	9577	20000	5986	155278
V <sub>3</sub> F <sub>4</sub>	11675	38390	50065	30580	10860	4870	3260	6850	23850	80270	130335	10427	20000	6517	167279

Note: V<sub>1</sub>F<sub>1</sub>= 75 Cabbage + no fertilizer, no manure and no pesticide; V<sub>1</sub>F<sub>2</sub>= 75 Cabbage + cow dung and bio-pesticide; V<sub>1</sub>F<sub>3</sub>= 75 Cabbage + poultry and bio-pesticide; V<sub>1</sub>F<sub>4</sub>= 75 Cabbage + recommended chemical fertilizer and chemical pesticide; V<sub>2</sub>F<sub>1</sub>= Succession Taki + no fertilizer, no manure and no pesticide; V<sub>2</sub>F<sub>2</sub>= Succession Taki + cow dung and bio-pesticide; V<sub>2</sub>F<sub>3</sub>= Succession Taki + poultry and bio-pesticide; V<sub>2</sub>F<sub>4</sub>= Succession Taki + recommended chemical fertilizer and chemical pesticide; V<sub>3</sub>F<sub>1</sub>= Succession Japani + no fertilizer, no manure and no pesticide; V<sub>3</sub>F<sub>2</sub>= Succession Japani + cow dung and bio-pesticide; V<sub>3</sub>F<sub>3</sub>= Succession Japani + poultry and bio-pesticide; V<sub>3</sub>F<sub>4</sub>= Succession Japani + recommended chemical fertilizer and chemical pesticide.

**Appendix- IV: Some plates of the research**



**Plate a. Final land preparation for cabbage seedling planting**



**Plate b. Plots are isolated from each treatment in the experiment**



**Plate c. Cabbage seedling planting**



**Plate d. Watering of Cabbage seedling**



**Plate e. Spraying Neem oil in the field**



**Plate f. After tagging of Cabbage seedling**





**Plate f. Measurement of plant height, leaf length and leaf breadth of cabbage seedling**



**Plate f<sub>1</sub>. Measurement of plant height, leaf length and leaf breadth of cabbage seedling**



**Plate g. Cabbage under mango based agroforestry system**



**Plate h. Harvesting of Cabbage**



**Plate i. Measuring the weight of curd**



**Plate j. Measuring the size of curd**

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