# Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system

काशी हिन्दू विश्वविद्यालय BANARAS HINDU UNIVERSITY

BHU capital of knowledge

**THESIS**

submitted in partial fulfilment of the requirements for the award to the degree of

*Master of Science (Agriculture)*

*in*

*Agroforestry*


Submitted by

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## CERTIFICATE

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**Office of the Registrar (Academic),**
**Banaras Hindu University**
**Varanasi – 221005 (India)**

**Through** The Head, Department of Agronomy,
Institute of Agricultural Sciences,
BHU, Varanasi- 221 005.

**Sir,**

I have great pleasure in forwarding the thesis entitled **"Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system"** submitted by **Ms. Komal Kiran (Examination Roll No. 19430AGF-011; Enrolment No. 422745)** in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Agroforestry,** Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that she has completed the requisite residential requirements as contained in the statutes of the university.

I certify that the entire scheme of investigation presented herein was planned and carried out solely by the candidate under my guidance and supervision. The data presented in the thesis, to the best of my knowledge and belief, are genuine and original.

Thanking you,

Yours faithfully,

**Forwarded by**

**(J.K. Singh)**
**Supervisor**

# Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system

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**INSTITUTE OF AGRICULTURAL SCIENCES**
**BANARAS HINDU UNIVERSITY**
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***Date:*** *-09-2021*
***Place:*** *Varanasi* *(Komal Kiran)*

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# LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| **%** | : | Percent |
| **@** | : | at the rate of -1 or / per |
| **AF** | : | Agroforestry |
| **Agri** | : | Agriculture |
| **Agri-horti** | : | Agri-horticultural system |
| **C** | : | degree Celsius° |
| **Cm** | : | centimetre |
| **DAS** | : | Days after Sowing |
| ***et al.*** | : | and others |
| **Fig.** | : | Figure |
| **ha** | : | hectare |
| **i.e.** | : | that is |
| **K** | : | Potassium |
| **$K_2O$** | : | Potassium oxide |
| **Kg** | : | kilogram |
| **M** | : | meter |
| **Max.** | : | maximum |
| **mg** | : | milligram |
| **Mha** | : | million hectare |
| **Min.** | : | minimum |
| **mm** | : | millimetre |
| **N** | : | Nitrogen |
| **NS** | : | Non-Significant |
| **P** | : | Phosphorus |
| **$P_2O_5$** | : | Phosphorus pentaoxide |
| RBD | : | Randomized Block Design |
| **S. No.** | : | Serial Number |
| **Sem±** | : | Standard Error (Mean) |
| **WAC** | : | World Agroforestry Centre |

# INTRODUCTION

Agroforestry system is diversified in several branches such as agri-horticultural system, silvopastoral system, home gardens and protein banks. Mostly farmers establish agroforestry system consisting of fruit trees and agricultural crops known as agri-horti cultural system. Citrus, Ber, Aonla, Wood apple, Guava are major promising fruit crops suitable for Agri-horti system. It reduces risk of income loss as well as have aesthetic value. Agroforestry is being practised in eastern and central Uttar Pradesh due to large scale adoption, particularly in degraded and marginal land but western Uttar Pradesh is much more ahead in terms of agroforestry practices as compared to other regions of the state. This region has well established agroforestry models due to the presence of wood based industries, which supports tree based agroforestry farmers to produce raw material (Rajput *et al.* 2019). Fruit based agroforestry system is mostly practised in this state. Popularly practised systems are based on eucalyptus, shisham, poplar and fruit trees like *Artocarpus heterophyllus* (Jackfruit), *Psidium guajava* (guava), banana, wood apple and various citrus fruits.

**Indian Mustard** [*Brassica juncea* (L.) Czern & Cosson] occupies an area of 36.59 million hectares (m ha) all over the world, production and yield during 2018-19 was 72.37 million tonnes (mt) and 1980 kg $ha^{-1}$ respectively. Globally, India contributes to 9.8% of total production. Mustard plants are easy and inexpensive to grow which can also tolerate extreme heat conditions and can survive in different types of soil as well as agroforestry system. In India mustard occupies 6.78 million hectares of area with production of 9.12 million tonnes and yield of 1345 kg $ha^{-1}$ during 2019-2020. Rajasthan is the highest producer of mustard having an area of 2.95 million hectare.

Mustard oil contributes to one-third of total edible oil production in India. It is mostly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat. Mustard crop is the main source of income in rain fed areas, especially to marginal and small farmers as it can survive in scarce conditions with low resource conditions. Water requirement of mustard is too low (80 to 240 mm) because of which it can easily be grown in rain fed areas.

**Phosphorus (P)** is an important element for the feasible production of *Brassica* species. Root system of mustard requires phosphorus for strong withholding of soil. Deficiency of the element causes dwarfism in plants with stunted roots. With severe deficiency, plants will be spindly, and if extremely deficient, mustard plants will have purple discolouration of the stems and leaves as well as be stunted. Phosphorus is also vital for energy transformation reactions and respiration process. It constituents for nucleoproteins and nucleic acid and therefore plays an important role in hereditary transformation. Phosphorus availability from soil is not sufficient for growth in many soils because of its immobilization so it is important to apply phosphorus in the form of fertilizer. Fixation of phosphorus present in soil is increased with time of contact between soil particles and soluble phosphorus. Thus, applying phosphorus just before sowing of seed is more efficient for absorption of fertilizer phosphorus. Soil pH is one of the most important factor which effects growth and development of crops. Low pH of soil tends to be acidic in nature which retards the growth of plants by reducing the uptake of plant nutrients. Acid soil accounts for 48 to 49 m ha arable land whereas 30% of cultivable land is acidic in nature. Excess weathering, uneven rainfall, humid climate are causes of acidic soil. Fertilizer management of such soils should be concerned. Soil acidity has indirect and direct effect on crops. Low pH shows direct effect due to increase in the concentration of $H^+$, $Al^+$ which becomes toxic to soil microorganisms and plants. Indirect effects include effect of pH on organic matter decomposition and nutrient availability. Seed/pod filling of oilseed crop is hampered when grown under high acidic soil condition (Sarkar, 2013). Liming is very common management practise to neutralize the active acidity due to aluminium and hydrogen ions in the soil solution. Application of lime in acidic soil can increase the pH of soil, availability of phosphorus, nitrogen mineralization, calcium exchangeable capacity and decrease acid saturation percentage. Liming material are oxides, carbonates and hydroxides of magnesium and calcium. Calcium ions replace the adsorbed aluminium ions and thus reduce the pH of soil. Industrial wastes, such as lime sludge from paper mills, pressmud, basic slag, phosphogypsum are also good source of liming material. Plants grow healthier roots because application of lime reduces aluminium toxicity. Healthy and strong root system makes plant drought tolerance. Nutrient solubility is also increased with higher pH, so there is better availability of nutrients.

***Vindhyan*** region of Uttar Pradesh is characterized by red loamy soil having low water holding capacity where raising crops under agroforestry system helps in enhancing soil quality as well as increases the yield of crops. Rajiv Gandhi South Campus, BHU of *Vindhyan* region comprises of wood apple, custard, guava, aonla based agri-horticultural systems. Farmers residing in Mirzapur (*Vindhyan* region) are also dependent on cultivation of crops like mustard and lentil during *rabi* season for economic stability. The climate of *Vindhyan* region is characterized by hot summer and low rainfall. Summer temperature goes up to 50°celsius. Rainfall is also very little which ranges from 750 to 1200 mm. The region comprises of underlying rocks with sandy to sandy loam soil. Acidic soil of the region is a problem for farmers as productivity of crops are not economically feasible.

Keeping above points in view the present study entitled "Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system" was planned with following objectives-

1. To study the effect of phosphorus and lime levels on growth and yield of Indian mustard under wood apple based agri-horti system.
2. To study the effect of phosphorus and lime levels on N, P, K uptake by mustard.
3. To study about relative economics of the treatments under wood apple based agri-horti system.

*Chapter II*

# REVIEW OF LITERATURE

## 2.1 Effect of phosphorus levels

### 2.1.1 Effect of phosphorus levels on plant height

**Mani *et al.* (2006)** conducted an experiment to study the effect of ammonium sulphate and DAP on yield and nutrient uptake by mustard. The experiment consisted of three levels of phosphorus (0, 40 and 60 kg $P_2O_5$ ha$^{-1}$) and three levels of sulphur (0, 20, 30 kg S ha$^{-1}$). It was observed that maximum plant height was obtained at 60 kg $P_2O_5$ ha$^{-1}$ with 4.99% increment and number of siliquae with increment of 11.74% whereas increasing sulphur from 0 to 30 kg ha$^{-1}$ individually increased the plant height by 1.87% and number of siliqua by 5.01%.

**Kumar and Yadav (2007)** conducted an experiment on alluvial soil with sand and gravels, in two consecutive winter season to find the optimum dose of sulphur and phosphorus for Indian mustard (*Brassica Juncea* L.) Experiment consisted of four levels of phosphorus (0, 13, 26 and 39 $P_2O_5$ kg ha$^{-1}$) and four levels of sulphur (0, 15, 30, 45 kg S ha$^{-1}$) which were applied in the form of diammonium phosphate and elemental sulphur. The design of the experiment was split plot with three replications. It was observed that the optimum dose for sulphur was 47.5 and 40.2 whereas optimum dose for phosphorus was 44.2 and 40.2 in two consecutive years as it gave maximum height and yield at harvest**.**

**Singh *et al.* (2008)** conducted an experiment on black cotton soil revealed that Varuna variety of mustard showed linear increment with increase in level of $P_2O_5$ up to 60 kg ha$^{-1}$.

**Birle *et al*. (2011)** conducted an experiment to find the effect of phosphorus and zinc on yield and chemical composition of mustard grown on sodic soil of Gwalior and revealed that application of 60 kg $P_2O_5$ ha$^{-1}$ increased the height of plant by 17.84% over the control.

**Yadav *et al.* (2014)** conducted an experiment to study the effect of phosphorus and sulphur at farmer's field of Ballia District. The experiment was carried out at randomized block design with three levels of phosphorus (20, 40, 60 kg $P_2O_5$ $ha^{-1}$) and sulphur (20, 30 and 40 kg S $ha^{-1}$). It was observed that maximum plant height was at 60 kg $P_2O_5$ and 40 kg S $ha^{-1}$.

**Solanki *et al.* (2015)** carried an experiment to study the effect of phosphorus, sulphur and PSB on yield of Indian mustard (*Brassica juncea* L.) and available macronutrients in soil. The experiment was consisted of four levels of sulphur (0, 30, 40 and 50 kg S $ha^{-1}$), four levels of phosphorus (0, 30, 40, 50 kg $P_2O_5$ $ha^{-1}$) and two levels of seed inoculation with phosphate solubilizing bacteria (PSB). It was noticed that maximum plant height was obtained with 40 kg $P_2O_5$ $ha^{-1}$.

**Nath *et al.* (2018)** studied the effect of phosphorus and sulphur on yield attributes, yield and economics of mustard at Banaskantha District of Gujrat. It was revealed that maximum plant height at harvest was observed at 75 kg $P_2O_5$ over 25 kg and 50 kg $P_2O_5$ $ha^{-1}$.

**Potdar *et al.* (2019)** conducted an experiment at Udaipur to study the effect of integrated phosphorus management on growth, yield and quality of Indian mustard (*Brassica juncea* L.) where it was noticed that yield and growth was significantly affected by different levels of phosphorus. Maximum height was observed with the application of 60 kg $P_2O_5$ over the control and was at par with 40 kg $P_2O_5$ $ha^{-1}$.

### 2.1.2 Effect of phosphorus on growth parameters

**Rao *et al.* (2002)** conducted an experiment to study the effect of organic manure, gypsum and phosphorus in preceding groundnut on soil fertility and productivity of Indian mustard. The effect of residual organic manure increased the seed yield owing to the effect of poultry manure and FYM manure which was 9.3 and 12.1% over the control. The residual effect of 60 kg $P_2O_5$ $ha^{-1}$ increased the seed yield by 9.7% over 20 kg $P_2O_5$ $ha^{-1}$, 1000- seed weight, seed weight $plant^{-1}$ and number of siliquae $plant^{-1}$.

**Premi *et al.* (2004)** conducted a field experiment to study the effect of nitrogen and phosphorus levels on the growth, oil content and yield of mustard. It was declared that there was significant increase in number of siliquae per plant up to 120 kg N $ha^{-1}$ and number of seeds per siliqua up to 80 kg N $ha^{-1}$

**Birle *et al.* (2011)** conducted an experiment at Gwalior, Madhya Pradesh to study the effect of phosphorus and zinc on yield and chemical composition of mustard grown on sodic soil environment and proved that application of 60 kg $P_2O_5$ $ha^{-1}$ increased the number of branches by 43.19% over control and number of siliquae per plant by 36.7% over the control. There was maximum number of branches in the combined application of 60 kg $P_2O_5$ and 5 kg Zn $ha^{-1}$.

**Verma *et al*. (2012)** studied the effect of phosphorus and molybdenum on yield and quality attributing characters of mustard at Faizabad comprising of alluvial soil. It was noticed that number of branches $plant^{-1}$ and number of seeds $siliqua^{-1}$ increased with application of 60 kg $P_2O_5$ $ha^{-1}$ and 4 kg Mo $ha^{-1}$.

**Yadav *et al.* (2014)** conducted an experiment to study the effect of phosphorus and sulphur which was carried in randomized block design with three levels of phosphorus (20, 40, 60 kg $P_2O_5$ $ha^{-1}$) and sulphur (20, 30 and 40 kg S $ha^{-1}$). It was noticed that maximum number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$ and dry weight $plant^{-1}$ was obtained with the application of 60 kg $P_2O_5$ $ha^{-1}$ with 40 kg S $ha^{-1}$.

**Solanki *et al.* (2015)** carried out an experiment to study the effect of phosphorus, sulphur and PSB on yield of Indian mustard (*Brassica juncea* L.) and available macronutrients in soil. The experiment consists of four levels of sulphur (0, 30, 40 and 50 kg S $ha^{-1}$), four levels of phosphorus (0, 30, 40, 50 kg $P_2O_5$ $ha^{-1}$) and two level of seed inoculation with phosphate solubilizing bacteria (PSB). Application of 40 kg $P_2O_5$ $ha^{-1}$ showed higher branches $plant^{-1}$, number of siliquae $plant^{-1}$ and test weight in mustard over the control.

**Singh *et al*. (2015)** studied the effect of phosphorus, sulphur and zinc on siliqua plant$^{-1}$, test weight, and seed yield plant$^{-1}$ of mustard at Agra. The experiment was conducted in split plot design and the treatments included phosphorus (0, 30, 60 kg P ha$^{-1}$), sulphur (0, 20, 40 kg S ha$^{-1}$) and zinc (0, 5, 10 kg Zn ha$^{-1}$). It was recorded that application of 60 kg $P_2O_5$ with 40 kg S ha$^{-1}$ gave maximum siliquae plant$^{-1}$ and seed weight.

**Nath *et al.* (2018)** studied the effect of phosphorus and sulphur on yield attributes, yield and economics of mustard. It was observed that the maximum siliqua length was obtained at 75 kg $P_2O_5$ ha$^{-1}$ over 25 and 50 kg $P_2O_5$ ha$^{-1}$.

### 2.1.3 Effect of phosphorus in nutrient uptake

**Lanjewar (2005)** carried out an experiment to study the effect of phosphorus and sulphur application on nutrient uptake of mustard. It was found that nutrient uptake was increased significantly with increase in sulphur and phosphorus up to 60 kg S ha$^{-1}$ and 50 kg $P_2O_5$ ha$^{-1}$.

**Krishna *et al.* (2005)** conducted an experiment to study the effect of phosphorus, sulphur and zinc fertilization on quality of mustard grown under semi-arid conditions. Effect of 60 kg $P_2O_5$ and 30 kg $ZnSO_4$ ha$^{-1}$ gave higher glucosinolate and protein content.

**Mir *et al.* (2006)** conducted an experiment to study the effect of phosphorus, sulfur and PSB on blackgram (*Phaseolus mungu*) and its residual effect on mustard (*Brassica juncea* L.) and soil properties. It was recorded that higher sulphur and phosphorus uptake was seen at 40 kg S and 60 kg $P_2O_5$ ha$^{-1}$.

**Deo *et al.* (2009)** conducted an experiment during two consecutive *rabi* seasons to study the effect of phosphorus and zinc on mustard yield, nutrient uptake and oil content in gypsum treated sodic soil. It was observed that with increasing application of zinc and phosphorus the uptake of zinc and phosphorus was also increased but the uptake of phosphorus was decreased with higher doses of zinc. It was estimated that 60 kg $P_2O_5$ and 5 kg zinc ha$^{-1}$ gave maximum nutrient uptake and oil content of mustard over 30 kg $P_2O_5$, 45 kg $P_2O_5$ ha$^{-1}$ and 0, 10 kg zinc ha$^{-1}$.

**Gangwal *et al*. (2011)** conducted an experiment during the two consecutive *rabi* season to study the effect of phosphorus, sulphur and phosphate solubilizing bacteria on growth and nutrient uptake by mustard in loamy sand soil. The treatment consisted of three level of phosphorus (0, 25, 50 kg $P_2O_5$ $ha^{-1}$), three level of sulphur (0, 20, 40 kg S $ha^{-1}$) and two level of PSB (no inoculation and with inoculation with Aspergillus Niger strain-1). It was estimated the combined application of PSB (inoculation) with 50 kg $P_2O_5$ $ha^{-1}$ and 40 kg S $ha^{-1}$ showed maximum nutrient content in seed and straw which declared higher nutrient uptake.

**Mani *et al.* (2015)** conducted an experiment to study the effect of ammonium sulphate and DAP on yield and nutrient uptake by mustard. The experiment consisted of three levels of phosphorus (0, 40 and 60 kg $P_2O_5$ $ha^{-1}$) and three levels of sulphur (0, 20, 30 kg $ha^{-1}$). It was seen that maximum uptake of phosphorus (14.99 kg $ha^{-1}$) was obtained with application of 60 kg $P_2O_5$ $ha^{-1}$ but sulphur uptake decreased with increasing phosphorus whereas maximum sulphur uptake was noticed with application of 30 kg S $ha^{-1}$.

**Singh *et al.* (2015)** studied the effect of phosphorus and sulphur on yield, quality and nutrient uptake by Indian mustard where it was found that treatment combination of 60 kg $P_2O_5$ with 60 kg S $ha^{-1}$ showed there was increase in uptake of N, P and S from 23.78 to 59.06, 2.27 to 7.24 and from 3.83 to 20.55 kg $ha^{-1}$.

**Singh and Thenuwa (2016)** conducted a field experiment during the *rabi* season to study the effect of phosphorus and sulphur on yield and nutrient uptake by mustard. The fertilizers were applied in the form of DAP and ammonium sulphate. It was stated that maximum nutrient uptake was noticed at 60 kg $P_2O_5$ and 40 kg sulphur $ha^{-1}$.

### 2.1.4 Effect of phosphorus on yield

**Ram *et al.* (2000)** studied the effect of phosphorus, sulphur and phosphate solubilizing bacteria on yield, oil content and nutrient uptake by mustard. Higher stover, seed and oil yield was obtained with the application of 30 kg $P_2O_5$ $ha^{-1}$ over the control.

**Deo *et al.* (2003)** conducted an experiment during the two consecutive *rabi* season to study the effect of phosphorus and zinc on mustard yield, nutrient uptake and oil content in gypsum treated sodic soil. It was noticed that maximum yield was at 60 kg $P_2O_5$ $ha^{-1}$ and 5 kg zinc $ha^{-1}$ when compared to other three levels of phosphorus (0, 30, 45 kg $ha^{-1}$) and other two levels of zinc (0, 10 $ha^{-1}$)

**Giri *et al.* (2005)** studied the effect of sulphur and phosphorus application on growth and yield of mustard (*Brassica juncea* L). The experiment was conducted in factorial randomized block design with three levels of phosphorus (30, 40, 50 kg $P_2O_5$ $ha^{-1}$) and four levels of sulphur (0, 20, 40, 60 kg S $ha^{-1}$). It was recorded that 50 kg $P_2O_5$ $ha^{-1}$ gave maximum seed yield whereas there was non-significant effect of interaction between phosphorus and sulphur.

**Mani *et al.* (2005)** conducted an experiment to study the effect of ammonium sulphate and DAP on yield and nutrient uptake by mustard. The experiment consisted of three levels of phosphorus (0, 40 and 60 $P_2O_5$ kg $ha^{-1}$) and three levels of sulphur (0, 20, 30 kg S $ha^{-1}$). It was seen that highest seed yield (104.06 g $plot^{-1}$) was recorded with phosphorus at 60 kg $P_2O_5$ and 30 kg S $ha^{-1}$.

**Gangwal *et al.* (2006)** conducted an experiment during the two consecutive *rabi* season to study the effect of phosphorus, sulphur and phosphate solubilizing bacteria on growth and nutrient uptake by mustard in loamy sand soil. The treatment consisted of three level of phosphorus (0, 25, 50 kg $P_2O_5$ $ha^{-1}$), three level of sulphur (0, 20, 40 kg S $ha^{-1}$) and two level of PSB (no inoculation and with inoculation with *Aspergillus Niger* strain-1). It was estimated the combined application of PSB (inoculation) with 50 kg $P_2O_5$ and 40 kg S $ha^{-1}$ showed maximum seed and straw yield.

**Mire *et al*. (2010)** conducted an experiment to study the effect of fertilizers on the yield of mustard (*Brassica juncea* L. Czern and Coss var. Alankar) at Aligarh. The treatment combination included phosphorus and potassium applied as monocalcium superphosphate and muriate of potash each at rate of 30, 60, 90 kg $P_2O_5$ and $K_2O$ $ha^{-1}$.

It was observed that 60 kg $P_2O_5$ alone and 60 kg $P_2O_5$ with 60 kg $K_2O$ ha$^{-1}$ increased the seed yield due to increase in seed pod$^{-1}$ and increase in pod plant$^{-1}$.

**Lone *et al.* (2010)** conducted an experiment to study the effect of different combinations of phosphorus and potassium each of them comprising of 30, 60, 90 kg $P_2O_5$ and $K_2O$ ha$^{-1}$. Maximum seed yield was observed with the individual application of 60 kg $P_2O_5$ and 60 kg $P_2O_5$ + 60 kg $K_2O$ ha$^{-1}$.

**Solanki *et al.* (2015)** carried an experiment to study the effect of phosphorus, sulphur and PSB on yield of Indian mustard (*Brassica juncea* L.) and available macronutrients in soil. The experiment consisted of four levels of sulphur (0, 30, 40 and 50 kg S ha$^{-1}$), four levels of phosphorus (0, 30, 40, 50 kg $P_2O_5$ ha$^{-1}$ ) and two level of seed inoculation with phosphate solubilizing bacteria (PSB). Maximum grain yield was observed with 50 Kg $P_2O_5$ + 50 kg S ha$^{-1}$+ PSB. There was slight decrease in pH and EC and increase in available nitrogen, phosphorus, potassium, sulphur and organic carbon in the soil after harvest of soil samples.

**Singh *et al*. (2015)** studied the effect of phosphorus and sulphur on yield, quality and nutrient uptake by Indian mustard where it was found that treatment with 30 kg and 60 kg $P_2O_5$ ha$^{-1}$ increased the grain yield by 7.98 to 10.49 and 14.8 q ha$^{-1}$, respectively over no phosphorus. Stover yield was also maximum with the treatment combination of 60 kg $P_2O_5$ with 60 kg S ha$^{-1}$.

**Singh and Thenuwa (2016)** conducted a field experiment during *rabi* season to study the effect of phosphorus and sulphur on yield and nutrient uptake by mustard. The fertilizers were applied in the form of DAP and ammonium sulphate. It was stated that maximum yield was noticed at 60 kg $P_2O_5$ and 40 kg sulphur ha$^{-1}$.

**Potdar *et al*. (2019)** conducted an experiment to study the effect of integrated phosphorus management on growth, yield and quality of mustard (*Brassica juncea* L.) whereas it was observed that there was higher seed and straw yield with application of phosphorus at 60 kg $P_2O_5$ ha$^{-1}$ over the control and at par with 40 kg $P_2O_5$ ha$^{-1}$. The seed yield was increased by 36% and straw yield was increased by 35.13%.

## 2.2 Effect of lime levels

### 2.2.1 Effect of lime application on soil properties

**Holford *et al*. (1994)** carried an experiment which was conducted to study the long term effects on soil phosphorus solubility and sorption in eight acidic soil. It was found that there was maximum increase in phosphorus availability with the application of lime at 5 t $ha^{-1}$.

**Curtin *et al.* (1998)** studied the effects of acidity on mineralization: pH-dependence of organic matter mineralization in weakly acidic soils. It was found that the pH of two acidic soils was raised to two to three times from 5.7 to 7.3 with the application of $Ca(OH)_2$. There was increase in N mineralization as well as increase in carbon content of soil.

**Whalen *et al.* (2002)** studied the effect of cattle manure and lime amendments to improve crop production of acidic soils in northern Alberta. It was found that the soil pH was increased from 4.8 to 6.0 with the increased application of lime.

**Arshad *et al.* (2012)** studied soil and crop response to wood ash and lime application in acidic soil. It was found that there was increase in soil pH and available phosphorus in order of Wood ash>agricultural lime>control.

**Chimdi *et al.* (2012)** carried an experiment to study the effect of liming on acidity related chemical properties of soils of different land use systems in western Oromia, Ethiopia. It was observed that application of lime at the rate of 10 t $ha^{-1}$ increased the soil pH, available Phosphorus and reduced the acid saturation percentage.

**Osundwa *et al.* (2013**) carried out an experiment to find out the influence of agricultural lime on soil properties and yield of wheat on acidic soils of Uasin Gishu country, Kenya. The experiment was conducted in split plot design with two varieties of wheat at the main plot and lime treatments as subplots. Soils were analyzed to observe the effect of lime on soil pH, other nutrients and available phosphorus. Lime was applied at the rate of 0.0, 0.5, 1.0, 1.5 and 2.0 tonnes $ha^{-1}$. It was noticed that there was increase in soil pH and available phosphorus with increase in the level of lime application.

**Buni *et al.* (2014)** studied the effects of liming on acidic soils on enhancing soil properties and yield of haricot bean. The experiment was conducted in randomized complete block design with three replications. The treatments consisted of four levels of lime (0, 125, 250, 375 kg $ha^{-1}$). It was revealed that the soil pH increased from 5.03 to 6.72 with the application of 375 kg $ha^{-1}$ lime and there was reduction in exchangeable acidity.

**Gabriel *et al.* (2018)** conducted an experiment to study the lime and gypsum application on initial growth of eucalyptus and change in soil chemical properties. It was found that the soil pH, base saturation and exchangeable calcium was increased with increasing level of lime.

### 2.2.2 Effect of lime application on yield attributes

**Whalen *et al.* (2002)** studied the effect of cattle manure and lime amendments to improve crop production of acidic soils in northern Alberta. It was noticed that the yield of canola and wheat was increased with increase in the application of lime.

**Saha *et al.* (2010)** studied the effect of Integrated Nutrient Management on soil physical properties and crop productivity where it was found that the yield of mustard and maize was significantly increased with the application of NPK (100%) + lime + biofertilizer + FYM when compared to control over the other plants. It was stated that the application of inorganic fertilization with lime and organic manure enhanced the physical properties of soil which led to increase the productivity of crops.

**Pal (2011)** conducted an experiment to study the effect of lime, organic manure and greenleaf manuring on sustainable production of greengram-mustard cropping sequence and observed that highest yield of green gram was obtained at 5 tonnes of FYM along with 20% lime $ha^{-1}$.

**Effa *et al.* (2012)** conducted an experiment to evaluate the effect of levels of lime (0, 500, 1000 kg $ha^{-1}$) and nitrogen (0, 40, 80, 120 kg $ha^{-1}$) and found that 500 kg lime $ha^{-1}$ gave maximum yield which was 18.3 % more over the control.

**Osundwa *et al.* (2013)** carried out an experiment to find out the influence of agricultural lime on soil properties and yield of wheat on acidic soils of Uasin Gishu country, Kenya. The experiment was conducted in split plot design with two varieties of wheat at the main plot and lime treatments as subplots. Soils were analyzed to observe the effect of lime on soil pH, other nutrients and available Phosphorus. Lime was applied at the rate of 0.0, 0.5,1.0, 1.5 and 2.0 tonnes $ha^{-1}$. It was stated that the yield of wheat increases with increase in the application of lime which was due to soil acidity amendment. There was a positive correlation between the lime application, available phosphorus and yield of wheat.

**Buni (2014)** studied the effects of liming on acidic soils on enhancing soil properties and yield of haricot bean. The experiment was conducted in randomized complete block design with three replications. The treatments consisted of four levels of lime (0, 1250, 2500, 3750 kg $ha^{-1}$). It was revealed that yield of haricot bean increased with increasing level of lime. The yield of lime showed positive correlation with CEC(r=0.28), available phosphorus (0.27), soil ph (r=0.23) and negative with exchangeable acidity (r=0.37).

**Kumar *et al.* (2014)** conducted an experiment to study the effect of lime in ricebean cultivars in foothills of northeastern India. Experiment was conducted in split plot design it consisted of four levels of lime as sub plot (control, 0.2, 0.4, 0.6 t $ha^{-1}$) and four varieties of ricebean as main plots (RBS-16, RBS-53, PRR-2, RCRB-4). The results revealed that the growth attributes and yield was significantly increased from 0 to 6 t $ha^{-1}$ of lime.

### 2.2.3 Effect of lime on growth attributes

**Workneh (2013)** studied the effect of nodulation and growth response of soybean to lime, *Bradyrhizobium japonicum* and nitrogen fertilizer in acid soil at

Melko, South western Ethiopia. It was found that the combining effect of lime and *Bradyrhizobium japonicum* increased the number of nodule, volume of nodule and dry weight of nodule when compared to unlimed soil and non-inoculated treatments. Number of branches and the height of plants in lime treated plot were more when compared to unlimed soil.

**Kisinyo (2013)** studied the effect of lime and phosphorus on soil acidity and maize production in western Kenya. Experiment consisted of three levels of phosphorus (0, 26 and 52 kg $ha^{-1}$) and four levels of lime (0, 2, 4 and 6 tons lime $ha^{-1}$). It was found that with increasing application of lime there was increase in the plant growth but the recovery of soil available phosphorus decreased with increasing the application of phosphorus. It was noticed that where there was application of 56 kg $ha^{-1}$ phosphorus and 56 kg $ha^{-1}$ phosphorus with lime there was need to reapply same phosphorus fertilizer because the availability of soil phosphorus was reduced. The experiment concludes that there is need for the application of both lime and phosphorus for the healthy growth of maize in Kenya.

**Lynrah *et al.* (2017)** conducted an experiment to study the effect of integrated nutrient manangement and lime on Soybean under Rainfed Condition of Nagaland. It was found that the application of lime at the rate of 1.5 t $ha^{-1}$ gave the highest growth attributes. There was maximum number of pods $plant^{-1}$, nodules $plant^{-1}$, number of branches $plant^{-1}$ at the rate of 1.5 t $ha^{-1}$ lime.

**Gabriel *et al.* (2018)** conducted an experiment to study the lime and gypsum application on initial growth of Eucalyptus and change in soil chemical properties. It was observed that the lime application has increased the shoot dry weight as well as benefits were noticed in the growth of seedlings.

## 2.3 Interaction effect of phosphorus and lime

**Mahler *et al.* (1985)** studied the influence of lime and Phosphorus on crop production in northern Idhao. Excess of ammonium Based N fertilizer for the growth of cereal crop have gradually made soil acidic in Idhao. It was observed that there was

9 to 16% increase in cereal yield and 20 % increase in spring pea with application of lime. There was more positive responses of interaction effect of lime and phosphorus in peas than in cereal crop. Cereal crops are more tolerant to acidic soil and therefore wheat exhibited greater response to phosphorus application.

**Fageria *et al*. (1995)** conducted an experiment on lime and phosphorus interactions in nutrient uptake by upland rice, corn, common bean and wheat in an Oxisol. Application of phosphorus and lime is very common practice for improving acidic soil conditions of temperate and tropical regions. It was observed that the increase in phosphorus have significantly increased the dry matter and uptake of all four crops whereas the application of lime improved the growth of common bean and corn but have shown negative impacts on growth of rice. Maximum dry weight of rice and wheat was seen at 175 mg $P_2O_5$ kg $ha^{-1}$ without lime but maximum dry weight of common bean was obtained at 175mg $P_2O_5$ kg $ha^{-1}$ kg with lime. It was concluded that overuse of lime decreased the uptake of phosphorus, Zinc, Manganese, Iron. Excess of lime also reduced the uptake of Potassium due to antagonist effect. Therefore excess use of Lime should be avoided but at the same time adequate amount of lime is useful to increase the pH of acidic soil.

**Sharma *et al.* (2002)** conducted an experiment to study the effect of lime and phosphorus on content and uptake of phosphorus in greengram-sesamum cropping sequence. The experiment was conducted in alflisol soil of Jorhat. It was concluded that the uptake of phosphorus was 50% higher with application of lime over no lime.

**Uzoho *et al.* (2010)** conducted an experiment to study the response of phosphorus and lime in maize on gas flare affected soils. The experiment was conducted in completely randomized block design. Treatment combination was phosphorus (0, 30) kg $ha^{-1}$ and lime (0, 1, 1.5 and 2.0) t $ha^{-1}$. It was observed that all the measured parameters exhibited better with the application of 30 kg $P_2O_5$ kg $ha^{-1}$ and lime 1.5 t $ha^{-1}$.

**Asrat *et al.* (2012)** studied the effect of integrated use of lime, mineral phosphorus fertilizer, use of lime on bread wheat (*Triticum aestivum*) yield, uptake and status of residual soil phosphorus on acidic soils on Gozamin. The experiment was conducted in factorial randomized block design. It was revealed that the lime application enhanced early germination of seed and the plant height was enhanced by the interaction of lime and phosphorus.

**Muindi *et al.* (2015)** conducted an experiment to study the effect of lime-aluminium-phosphorus interaction in acid soils of the Kenya Highlands. The experiment consisted of four levels of lime (0, 2.2, 5.2 and 7.4 t $ha^{-1}$) and four levels of phosphorus (0, 0.15, 0.30, and 0.59 g $ha^{-1}$). It was observed that lime-aluminium-phosphorus interaction increased extractable phosphorus, increased the soil pH and reduced exchangeable aluminium, phosphorus adsorption and standard phosphorus requirements (SPR). It was stated further that interaction effect of phosphorus and lime reduced phosphorus and aluminium adsorption rates.

**Opala (2017)** studied the influence of lime and phosphorus application on growth of maize in an acid soil. The experiment was conducted in completely randomized design with four levels of lime (0, 2, 10 and 20 t $ha^{-1}$) and three levels of phosphorus (0, 30, 100 kg $P_2O_5$ $ha^{-1}$). It was observed that with no application of lime, the dry matter increased with increasing amount of phosphorus but with application of lime, the dry matter increased from 0 to 30 kg $ha^{-1}$ and reduced from 0 to 100 kg $P_2O_5$ $ha^{-1}$. The maximum dry matter yield (13.8 g $pot^{-1}$) was observed with the combined effect of phosphorus at 30 kg $P_2O_5$ $ha^{-1}$ and lime at 2 $ha^{-1}$. It was concluded that moderate amount of phosphorus with lower amount of lime was appropriate for the soil and crop growth.

**Alemu *et al.* (2017)** studied the effect of lime and phosphorus fertilizer on acid soil properties and grain yield of barley at Bedi in western Ethopia. The experiment was conducted in complete randomized block design with three replications. The treatment consisted of five levels of lime (0, 0.55, 1.1, 1.65 and 2.2 t $ha^{-1}$) and four levels of phosphorus (0, 10, 20 and 30 kg $P_2O_5$ $ha^{-1}$). There was significant increase in the growth of barley with incremental application of lime and phosphorus. The maximum yield was obtained at 2.2 t $h^{-1}$ of lime and 20 kg $ha^{-1}$ of phosphorus. The soil pH increased from 5.3 to 5.9 with the application of lime.

**Varma *et al.* (2017)** studied the response of mungbean to NPK and lime under the conditions of *Vindhyan* Region of Uttar Pradesh. The treatment combination consisted of four levels of lime (control, 100, 200, 300 kg $ha^{-1}$) and NPK (Control, 75% of RDF, 100% RDF, 125% of RDF). The RDF of mungbean is 20, 40, 20 Kg $ha^{-1}$. It was observed that the highest seed yield was obtained at 100% RDF + 200 Kg $ha^{-1}$ lime when compared to other treatments.

**Dereje *et al.* (2019)** carried an experiment in split plot design with four levels each of lime (0,1.88,3.76,7.52 t $ha^{-1}$ ) and phosphorus (0,23,46,69 kg $ha^{-1}$) to study their effect on acid soil properties and sorghum grain and yield components where it was found that plant height was increased on an average up to 14.2 % by the application of 7.52 t $ha^{-1}$ lime over the control. Similarly yield was also increased with increasing levels of lime and phosphorus.

**Ameyu *et al.* (2020)** conducted an experiment to study the effect of lime and phosphorus on soybean grain yield and yield components at Mettu in South Western Ethopia. The experiment was conducted in Factorial Randomized block design. The treatment combination was lime (0, 1.41, 2.82, 4.23 and 5.64 t $ha^{-1}$) and phosphorus (0, 10, 20 and 30) kg $ha^{-1}$. It was observed that combined application of 30 Kg $P_2O_5$ $ha^{-1}$ and 5.64 lime t $ha^{-1}$ exhibited reclamation in soil and growth in Barley. It was further stated that application of lime with phosphorus improved the grain yield and yield related traits in crop.

## 2.4 Effect of agri-horticultural system on the yield

**Das *et al.* (2011)** conducted an experiment on yield, soil health and economics of Aonla (Emblica officinalis) based agri-horticultural systems in eastern India. The agri-hoticulture system consisted of aonla+turmeric, aonla+arbi and aonla+ginger. The results revealed that fruit production was maximum at Aonla+Turmeric system(13.30 tonnes $ha^{-1}$) which was followed by aonla+Arbi (11.71 tonnes $ha^{-1}$).There was significant reduction in yield of intercrops from 7.5-12% for turmeric, 15.7-25.3% for *arbi* crop and 12.2-19.3% for ginger when compared to the yield which was obtained from open field.

**Das *et al.* (2017)** conducted an experiment on performance of mango based agri-horticultural systems under rainfed plateau conditions of eastern India to analyze the profitability, soil fertility status, productivity of different crops and carbon sequestration of 20 different agri-horticultural systems and it was observed that there was huge increment in the growth of filler plants and mango.

**Johar (2017)** conducted an experiment to study the effect of light intensity on yield of wheat under *Eucalyptus tereticornis* based agri-silvi-horticultural system. The experiment consisted of Kinnow + Eucalyptus as agroforestry model and five year old plantation of Kinnow alone. It was stated that as both of them were evergreen in characteristics there was negative effect on the test crop when compared to Kinnow alone. The average grain yield of Kinnow + Eucalyptus agroforestry system was 40 per cent and that of Kinnow alone was 68.9 per cent. This was mainly due to the competition of light.

## 2.5 Effect of agri-horticultural system in economics

**Dyal (1996)** performed an experiment to optimize production and cash returns for Shivalik foothills. The experiment had *Leucaena Leucocephala* in borders to provide fuel wood and fodder, and the peripheral row consisted of *Citrus aurantiifolia* along with Carica papaya in the main plot and *Curcuma longa* (turmeric) as an intercrop. It was recorded that the mean annual net return under Agri-horti-silvicultural System was Rs 17746 and Rs 15092 and the net returned from the sole crop was Rs 7752 and Rs 3342 $ha^{-1}$. It was further stated that the Agri-silvi-horticultural system inhanced the cash flow as well as minimized the risk of drought.

**Singh *et al.* (2008)** studied the cultivation of crops in association of mango under two tier system of agroforestry and concluded that mango-based cropping systems maintained the flow of income as well as created an environment which was eco-friendly.

**Das *et al.* (2011)** conducted an experiment on yield, soil health and economics of Aonla (*Emblica officinalis*) based agri-horticultural systems in eastern India. The

Agri-hoticulture system consisted of Aonla+turmeric, Aonla+arbi and Aonla+ginger. The results revealed that the maximum cost benefit ratio was obtained from Aonla+turmeric (6.29) which was then followed by aonla+ginger (3.44) and was least from aonla+arbi (3.20).

**Devender *et al.* (2012)** studied assessment of two tier cropping system of agroforestry in Ambala district of Haryana where poplar based horti-Agro-Forestry models were adopted by farmers. Results revealed that the yield of inter sown crop was low after two to three years of poplar plantation but it was compensated from the income of timber production at the end of harvest. It was further stated that the poplar based agroforestry system was more economical than the monocropping system whereas it was a better alternative to wheat-paddy rotation in Indo-Gangetic plain.

*Chapter III*

# MATERIALS AND METHODS

The experiment, titled **"Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system",** was worked out during the winter (*Rabi*) season of 2019-2020. Equipment and technique for the success of work along with the field research is explained below in detail.

## 3.1 Experimental site

The experiment was piloted in the region of *Vindhyan*, ($25^0 10'$ latitude, $82^0 37'$ longitude and altitude of 427 meters above mean sea level) at Rajiv Gandhi South Campus, Barakachha, Banaras Hindu University, Mirzapur, Uttar Pradesh which is located at 8 km south west of Mirzapur city. Edaphic feature of *Vindhyan* region includes sandy loam soil with poor fertility and acidic pH which comes under rainfed condition. Agroclimatic zone of the region is III A (Semi-Arid Eastern Climatic Zone).

## 3.2 Climate and weather

Mirzapur is characterized by semi-arid to sub-humid climatic zone. Onset of monsoon on an average begins in third week of June and lasts up to September, it is the duration when 75% of rainfall is received by the area. March to May encompasses of dry season whereas December to mid of February is experienced by winter showers. January and May is experienced as coldest and hottest month respectively Temperature begins to show its increment from February and reaches maximum (45°C to 50°C) in May. The average rainfall based on last fifteen years is 1059 mm.

## 3.3 Weather during crop season

The weather data of the district was taken from Krishi Vigyan Kendra, Rajiv Gandhi South Campus of Banaras Hindu University presented in Fig. 3.1

### 3.3.1 Temperature (°C)

The monthly average minimum and maximum temperature, during the phase of crop growth, ranges from and respectively. The minimum temperature $7^0$C was observed in the month of December, whereas the maximum temperature $30^0$C was observed in the month of March.

### 3.3.2 Relative humidity (%)

The weekly mean maximum and minimum relative humidity, during the period of crop growth ranges from to 97 % to 85% and 25% to 56% respectively.

**Table 3.1: Weekly meteorological data during the period of experiment (*Rabi*, 2019-2020)**

| Std. Week No. | Months of 2019-2020 | Date | Rainfall (mm) | Temperature (°C) | | Relative humidity (%) | |
|---|---|---|---|---|---|---|---|
| | | | | Max. | Min. | Max. | Min. |
| 45 | Nov | 04-10 | 0.0 | 29 | 14 | 91 | 56 |
| 46 | | 11-17 | 0.0 | 29 | 11 | 90 | 41 |
| 47 | | 18-24 | 0.0 | 27 | 11 | 90 | 52 |
| 48 | | 25-1 | 1.0 | 27 | 14 | 92 | 56 |
| 49 | Dec | 02-08 | 0.0 | 25 | 10 | 92 | 26 |
| 50 | | 9-15 | 0.0 | 26 | 13 | 96 | 38 |
| 51 | | 16-22 | 0.0 | 24 | 09 | 95 | 36 |
| 52 | | 23-29 | 0.0 | 23 | 07 | 97 | 38 |
| 2 | Jan | 06-12 | 1.2 | 25 | 8 | 96 | 37 |
| 3 | | 13-19 | 0.0 | 28 | 9 | 96 | 41 |
| 4 | | 20-26 | 0.0 | 24 | 8 | 93 | 32 |
| 5 | | 27-02 | 1.4 | 27 | 9 | 91 | 32 |
| 6 | Feb | 03-09 | 0.0 | 29 | 11 | 94 | 29 |
| 7 | | 10-16 | 0.0 | 28 | 10 | 94 | 29 |
| 8 | | 17-23 | 0.0 | 33 | 11 | 85 | 27 |
| 9 | | 24-01 | 0.0 | 32 | 10 | 87 | 33 |
| 10 | Mar | 02-08 | 0.0 | 26 | 13 | 88 | 35 |
| 11 | | 09-15 | 0.0 | 20 | 15 | 86 | 32 |
| 12 | | 16-22 | 0.0 | 30 | 16 | 89 | 32 |

Observatory: www.accuweather.com/en/in/mirzapurcumvindhyachal.

**Table 3.2: Land use and other agricultural characteristics of the study area, Rajiv Gandhi South Campus (2019-2020)**

| S. No. | Agricultural parameters | Area (ha) |
|---|---|---|
| 1 | Geographical area (GA) | 2763acre |
| 2 | Forest area | 500 acre |
| 3 | Land not available for cultivation–non agricultural uses | 1880 acre |
| 4 | (a) Current fallows(b) Other fallows | (a) 900 acre (b) 450 acre |
| 5 | Pasture land | 200 acres |
| 6 | Net cropped area (NCA) | 375 acres |
| 7 | Area sown more than once | 78 acres |
| 8 | Total cropped area | 450 acres |
| 9 | Intensity of cropping | 120% |
| 10 | Cultivable waste land | 300 acres |
| 11 | Cultivated area | 450 acres |
| 12 | Barren land | 1888 acres |
| 13 | Land under misc. tree crops and groves | 515 acres |
| 14 | Net irrigated area | 100 acres |
| 15 | Gross irrigated area | 175 acres |
| 16 | Rainfed area | 275 acres |

### 3.4 Physico-chemical properties the soil

The soil, as a medium of plant support and growth, is leap to affect strongly and significantly the rate of growth and ultimately the final and profitable yield through its biotic and abiotic activities and geo-physio-chemical properties.

Soil samples were taken before conducting the experiment from a depth of 0-20 cm, taking all the possible safety measures prescribed for soil sampling. The samples were brought to the laboratory, air dried and crushed to pass through 2.0 mm sieve. The processed samples were subjected to appropriate mechanical and chemical analyses. The results thus obtained are presented in Table 3.3.

**Table 3.3. Physico-chemical properties the soil of experimental plot**

| **Soil properties** | | **Value** | **Method employed** |
|---|---|---|---|
| **a. Physical** | | | |
| Course sand | (%) | 10.33 | International Pipette Method (Piper, 1966) |
| Fine sand | (%) | 48.34 | |
| Silt | (%) | 19.39 | |
| Clay | (%) | 21.94 | |
| Textural class | | Sandy loam (Typic *Ustochrept*) | Black *et al*. (1967) |
| Bulk density | (Mg $m^{-3}$) | 1.42 | Black *et al*. (1967) |
| Particle density | (Mg $m^{-3}$) | 2.48 | Black *et al*. (1967) |
| **b. Chemical** | | | |
| pH (1:2.5 soil and water ratio) | | 5.91 | Beckman's Glass Electrode Method (Jackson, 1973) |
| Electrical conductivity | (dS $m^{-1}$ at $25^0C$) | 0.27 | Systronics Electrical Conductivity Meter (Jackson,1973) |
| Organic carbon | (%) | 0.28 | Rapid titration method (Piper, 1966) |
| Available nitrogen | (kg $ha^{-1}$) | 179.60 | Modified Alkaline Permanganate Method (Subbiah and Asija, 1956) |
| Available phosphorus | (kg $ha^{-1}$) | 13.10 | 0.03 *N* $NH_4F$ + 0.2 N HCL (Bray and Kurtz 1945) |
| Available potassium | (kg $ha^{-1}$) | 183.25 | 1*N* Neutral Ammonium Acetate Method (Jackson,1973) |

## 3.5 Cropping history of experimental field

The crop sequences followed in the experimental field during the past five years have been presented in Table 3.4. The cropping history of the experimental site clearly indicates that the field was not cropped continuously and kept fallow since last five years during *rabi* season.

**Table 3.4: Cropping history of experimental field.**

| Year | *Kharif* | *Rabi* |
|---|---|---|
| 2014-15 | Green gram | Fallow |
| 2015-16 | Sesamum | Fallow |
| 2016-17 | Green gram | Fallow |
| 2017-18 | Sesamum | Fallow |
| 2018-19 | Pearlmillet | Fallow |
| 2019-20 | Sesamum | Experimental crop |

## 3.6 Experimental details

The field experiment was evaluated during winter (*Rabi)* season of 2019-2020 under wood apple based agri-horti system, established on August, 2006 at a spacing of 7 x 7 meter with mustard as an intercrop. The experiment was laid in factorial randomized block design with two factors comprising of lime and phosphorus having three levels of each. Levels of lime was taken as 150, 300, 450 kg $ha^{-1}$ with levels of phosphorus as 30, 50, 70 kg $ha^{-1}$. Total number of treatment combinations was nine with one control (Fig. 3.5).

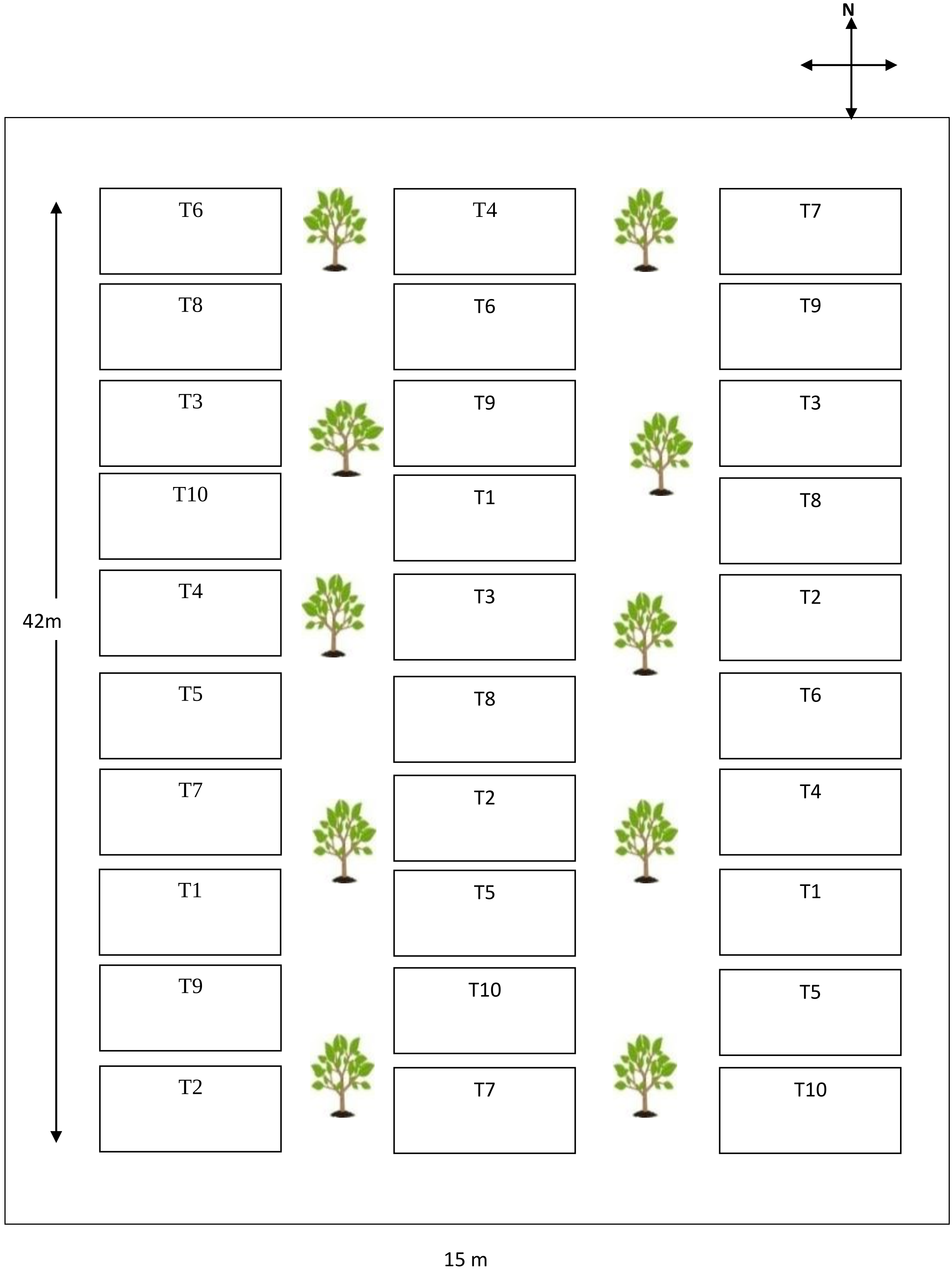
**Table 3.5: The treatments and their symbols are as under**

| S. No. | Symbol used | Treatments |
|---|---|---|
| 1. | $P_1L_1$ | 30 kg $P_2O_5$ + 150 kg lime $ha^{-1}$ |
| 2. | $P_1L_2$ | 30 kg $P_2O_5$ + 300 kg lime $ha^{-1}$ |
| 3. | $P_1L_3$ | 30 kg $P_2O_5$ + 450 kg lime $ha^{-1}$ |
| 4. | $P_2L_1$ | 50 kg $P_2O_5$ + 150 kg lime $ha^{-1}$ |
| 5. | $P_2L_2$ | 50 kg $P_2O_5$ + 300 kg lime $ha^{-1}$ |
| 6. | $P_2L_3$ | 50 kg $P_2O_5$ + 450 kg lime $ha^{-1}$ |
| 7. | $P_3L_1$ | 70 kg $P_2O_5$ + 150 kg lime $ha^{-1}$ |
| 8. | $P_3L_2$ | 70 kg $P_2O_5$ + 300 kg lime $ha^{-1}$ |
| 9. | $P_3L_3$ | 70 kg $P_2O_5$ + 450 kg lime $ha^{-1}$ |
| 10. | Control | No $P_2O_5$ + No lime |

**Note**: Open area plots were also maintained near the experimental field which was fertilized with 90, 50, 30 kg NPK and 300 kg lime $ha^{-1}$ for comparison with rest of the treatment.

**Table 3.6: The layout plan of experimental field is as follows**

| | | |
|---|---|---|
| Name of the crop | : | Indian Mustard (*Brassica juncea* L.) |
| Variety | : | Giriraj |
| Experimental design | : | Randomized block design (Factorial) |
| No. of treatment | : | 10 |
| No. of replication | : | 3 |
| Total number of plots | : | 10 x 3 = 30 |
| Block border | : | 1.0 m |
| Gross plot size | : | 4 m x 4 m = 16 $m^2$ |
| Net plot size | : | 3 m x 3 m = 9 $m^2$ |
| Plot border | : | 1 m |
| Row to row spacing | : | 30 cm |
| Plant to plant spacing | : | 10 cm |
| Wood apple sown at | : | 7×7 m |
| Variety of Wood apple | : | Narendra Bael-1 |




.**Figure 3.1: Layout of the experimental field**

### 3.7 Giriraj variety (DRMRI J 31)

Giriraj (DRMRIJ 31) is an Indian mustard (*Brassica juncea* L.) variety developed by ICAR Directorate of Rapeseed- Mustard Research, Bharatpur, Rajasthan. It can easily be identified on the basis of agro-morphological characteristics of semi appressed siliquae. It has long siliquae and bold sized seeds. The plants are tall in height with average height of 196 cm. Average seed yield is 2496 kg $ha^{-1}$ with average oil content of 1020 kg $ha^{-1}$

## 3.8 Agronomic practices

Cultural operations starting from field preparation to harvesting is shown in table 3.7.

### 3.8.1 Land preparation

For pulverization of soil, planking was done after ploughing with the help of repeated cultivator and disc plough. Layout was then plotted according to the experimental design.

### 3.8.2 Phosphorus level

Diammonium phosphate was chosen to be the source of phosphorus. Amount of phosphorus was estimated separately according to the experimental treatment combinations. Levels of phosphorus were $P_1$ (30 kg $P_2O_5$ $ha^{-1}$), $P_2$ (50 kg $P_2O_5$ $ha^{-1}$) and $P_3$ (70 kg $P_2O_5$ $ha^{-1}$).

### 3.8.3 Lime application

Slag lime was taken as the source of lime. Levels of lime were ($L_1$ 150 kg, $L_2$ 300 kg, $L_3$ 450 kg $ha^{-1}$). The levels of lime were estimated separately according to the treatment combinations.

### 3.8.4 Seed and sowing

The seeds were sown manually in row. Seed rate at 5 kg $ha^{-1}$ was kept for proper maintenance of plant population. Spacing of 10 cm was maintained within row between plant to plant.

### 3.8.5 Thinning and intercultural operation

Thinning was done after 15 days of sowing to remove extra plants. Weeding was done by *khurpi* after 30 days of sowing.

### 3.8.6 Harvesting and threshing

Crop was harvested after full ripeness. Collection from frontier rows were done first and kept apart. With the help of sickle net plots were harvested and left on the field for 3 to 4 days. Dried crops were then made in a bundle and was taken for threshing. Bundle weight was taken for seed and stover yield prior to threshing of bundles.

## Table 3.7 Schedule of field operations

| S. No. | Operations | Date |
|---|---|---|
| (A) | Pre-sowing operations | |
| 1. | Preparatory tillage | |
| | Tractor with cultivator | 12.11.2019 |
| | Ploughing with rotavator | 13.11.2019 |
| 2. | Layout | 14.11.2019 |
| (B) | Sowing operation | |
| 1. | Fertilizer and sowing operation | 16.11.2019 |
| (C) | Fertilizer application(s) | |
| 1. | NPK basal | 16.11.2019 |
| 2. | N Top dressed and nitrogen | 16.12.2019 |
| (D) | Cultural operation(s) | |
| 1. | Thinning | 1.12.2019 |
| 2. | Weeding | |
| | At 20 DAS | 6.12.2019 |
| | At 40 DAS | 26.12.2019 |
| 3. | First Irrigation | 16.12.2019 |
| 4. | Second Irrigation | 17.01.2020 |
| 5. | Insecticide spraying | 15.02.2020 |
| 6. | Harvesting | 21.03.2020 |
| 7. | Threshing | 25.03.2020 |

## 3.9 Biometric observations

Five plants from each plot was selected randomly for recording observations of growth attributes at 30, 60, 90 days after sowing. Yield and yield attributes were recorded after harvesting of plants.

### 3.10 Growth parameters

#### 3.10.1 Plant height (cm)

Height of tagged plants which were randomly selected from each plot was measured from base of the plant up to growing tip of main stem. By taking the mean of observation of five plants the average plant height was calculated and was expressed in cm.

#### 3.10.2 Number of leaves plant$^{-1}$

Number of green leaves was counted for five plants from each plot and was assumed as average number of leaves plant$^{-1}$.

#### 3.10.3 Number of siliquae plant$^{-1}$

Total number of siliquae was counted per plant and was assumed as average no. of siliqua plant$^{-1}$.

#### 3.10.4 Dry matter accumulation plant $^{-1}$ (g)

Five plants from each plot were cut from the base of frontier rows for estimation of dry matter accumulation. Sample plots were dried at 72 ± 2$^{o}$C for 24 hours in an oven after sun drying to get constant dry weight. Average dry weight was then recorded in g plant$^{-1}$.

### 3.11 Yield attributing characters

#### 3.11.1 Number of branches plant$^{-1}$

Five randomly tagged plants were used for estimation of secondary branches.

### 3.11.2 Number of siliquae per plant

Number of siliquae was counted from five random plants and the average was taken out for siliquae plant $^{-1}$.

### 3.11.3 Siliqua length

Length of siliqua was measured with the help of linear scale of five randomly selected plants and average was estimated.

### 3.11.4 Number of seeds siliqua$^{-1}$

Siliquae from five random plants was collected from each plot and was split to obtain seeds from each siliqua which was later averaged to obtain seeds siliqua$^{-1}$.

### 3.11.4 Seed weight

From each plot, 1000 seeds were collected and weighed to estimate 1000 seeds weight in grams.

### 3.11.5 Seed yield (kg ha$^{-1}$)

The seeds of each plot was cleaned and dried and weighed to find out the yield which was later converted in Kilogram hectare$^{-1}$ by multiplying with appropriate conversion factor.

### 3.11.6 Stover yield (kg ha$^{-1}$)

After threshing stem and chaff, weight per plot was recorded and was summed up separately for different treatments which was later converted by multiplying with appropriate conversion factor.

### 3.11.7 Biological yield (kg ha$^{-1}$)

Biological yield is the total dry matter accumulation of plant system which is obtained by calculating seed and stover yield of each treatment separately.

### 3.11.8 Harvest Index

Donald and Hamblin (1978) formula was used for calculation of Harvest Index

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Where,

Economic yield = Seed yield (kg $ha^{-1}$)

Biological yield = Seed yield (kg $ha^{-1}$) + Stover yield (kg $ha^{-1}$)

## 3.12 Nutrient content (%)

Kjeldhal method (Jackson, 1973) was used for nitrogen content. Vanadomolybdate phosphoric acid yellow colour method (Jackson 1973) and Flame-photometric method (Jackson, 1973) was used, respectively for estimation of phosphorous and potassium content.

### 3.13 Nutrient uptake (kg ha$^{-1}$)

Nutrient uptake in seed and stover of mustard was calculated in kg $ha^{-1}$ in relation to dry matter production $ha^{-1}$ by using the formula.

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content (\%) x Yield (seed/straw) in kg /ha)}}{100}$$

Nutrient uptake by seed and straw was added to get the total nutrient uptake by the crop.

### 3.14 Quality Parameters

#### 3.14.1 Protein content

Protein content in seed and stover was estimated by multiplying nitrogen content with factor 6.25 (AOAC, Washington 1970)

#### 3.14.2 Protein yield (kg ha$^{-1}$)

Protein yield from seed and stover was calculated my multiplying protein content with seed yield and stover yield, respectively to obtain seed protein yield and stover protein yield.

### 3.14.3 Oil content oil yield (%)

Oil content in seed was analyzed with the help of Soxhlet's extraction method taking petroleum ether as a solvent (ISI, 1975) and later oil content was multiplied with seed yield to obtain oil yield.

## 3.15 Growth parameters of wood apple

The following growth parameters of wood apple, situated at border of the plot, were recorded at the scheduled dates.

### 3.15.1 Plant height (m)

Three trees were taken as sample from each replication. The height of the sample trees were recorded and the average was estimated. Tree height was measured from the base of the tree up to the tip.

| | Replication I | Replication II | Replication III | Average |
|---|---|---|---|---|
| Tree height (cm) | 8.0 | 8.2 | 7.4 | 7.8 |

### 3.15.2 Canopy (m)

Three trees were taken as sample from each replication. The canopy area of the sample trees were recorded with the help of meter tape and the average was estimated.

| | Replication I | Replication II | Replication III | Average |
|---|---|---|---|---|
| Canopy Spread (m) | 4.9 | 5.0 | 4.3 | 4.7 |

### 3.15.3 Stem girth (cm).

The stem girth of tree was recorded with the help of vernier caliper. Two diameters were taken at right angle to each other at diameter breast height and average was taken.

| | Replication I | Replication II | Replication III | Average |
|---|---|---|---|---|
| Girth (cm) | 57.7 | 60.9 | 54.8 | 57.8 |

#### 3.15.4 Shading (m)

The shading area of wood apple was recorded with the help of meter tape and measured as width and length in meter.

| Shading area (m) | | | | | |
|---|---|---|---|---|---|
| Replication I | | Replication II | | Replication III | |
| Length | Width | Length | Width | Length | Width |
| 4.0 | 3.42 | 4.13 | 3.45 | 3.9 | 3.2 |

#### 3.15.5 Yield (kg $ha^{-1}$)

Three trees from each plot was taken as sample and ripen fruits from each sample tree was collected. After weighing their cumulative weight it was converted into kg $ha^{-1}$ at the end of the experiment (month of March).It was picked when the fruit color changed from green to yellow.

| Fruit trees | Average Number of fruits tree ($ha^{-1}$) | Average Number of fruits $tree^{-1}$ | Average weight of $fruit^{-1}$ (g) | Fruit yield (kg $ha^{-1}$) | Rate (fruit ₹ $kg^{-1}$) | Gross income from fruit tree ( ₹ ha`) |
|---|---|---|---|---|---|---|
| Wood apple | 6120 | 30 | 500 | 3060 | 18 | 55080 |

### 3.16 Relative economics

Expenses in each operation was considered to find out the relative economics with a view to work out the validity of each treatment. The following aspects of economics was studied.

### 3.16.1 Cost of cultivation (` ha$^{-1}$)

Cost of cultivation was calculated by common rate of cultivation.

### 3.16.2 Gross return (` ha$^{-1}$)

Straw yield and seed yield ( kg ha $^{-1}$) was multiplied with the average market price of straw and seed of mustard to find out the calculated gross return.

### 3.16.3 Net return (` ha$^{-1}$)

Grass profit was deducted from the relative figures of cost of cultivation from each treatment to find out the net return.

Net return (Rs ha$^{-1}$) was calculated with the help of the following formula:

Net return (Rs ha$^{-1}$) = Gross return (Rs ha$^{-1}$) – Cost of cultivation (Rs ha$^{-1}$)

### 3.16.4 Benefit-cost ratio

Gross income was divided by cost of cultivation to find out benefit-cost ratio.It was estimated with the formula given below:

$$\text{Benefit} - \text{cost ratio} = \frac{\text{Net return (Rs. ha}^{-1})}{\text{cost of cultivation (Rs. ha}^{-1})}$$

## 3.17 Statistical analysis

Statistical analyses were acquainted for determining the significance of the treatment means and to state valid conclusions. “Analysis of Variance” was used for statistical analysis of the observed datas. F test (Variance ratio) was taken out for knowing the significance of the treatment effects. Standard error of mean was calculated in all cases. Critical difference (C.D.) at 5 % level of probability (Gomez and Gomez, 1976). Difference (C.D.) at 5 % level of probability (Gomez and Gomez, 1976) was used to test the differences between the mean of the treatments.

Standard error of mean (Sem) and critical difference (C.D.) were calculated for further comparison if the variance ratio (F test) was found significant at 5 % level of significance.

SEm± = $\sqrt{\frac{\text{Error sum of square}}{\text{n}}}$

C.D. at 5 % = SEm± × $\sqrt{2}$ ×t value at value at 5 % of error degree of freedom.

Tabular forms and figures are used for presentation of results wherever necessary.

*Chapter IV*

# EXPERIMENTAL FINDINGS

The results of field experiment entitled as "Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea L.*) under wood apple (*Aegle marmelos*) based agri-horti system" conducted at agroforestry farm of Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh during *rabi* season, 2019-2020 are presented in this chapter. The data relating to various criteria used for treatment evaluation were analyzed statistically using standard statistical methods to test their significance and results have been presented through tables.

## 4.1 GROWTH PARAMETERS

### 4.1.1 PLANT HEIGHT (cm)

Data demonstrated in the table 4.1 illustrates that plant height was significantly higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that plant height was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

### EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of plant height pointed out that it was increased with increasing age of crop and reached maximum at maturity. Increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$ increased the plant height at all the dates of observation. Further, data signified that application of 70 kg $P_2O_5$ have shown higher plant height at all dates of observation as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in height was up to 14.9 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data on plant height pointed out that it was increased with increasing age of crop and reached maximum at maturity. Increasing levels of lime from 150, 300, 450 kg $ha^{-1}$ increased the height of plant at all dates of observation. Further, data signified that application of 450 kg lime have shown higher plant height at all dates of observation as compared to 150 kg lime but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in height of plant was up to 7 per cent from 150 kg to 450 kg lime $ha^{-1}$.

### 4.1.2 NUMBER OF SECONDARY BRANCHES PLANT$^{-1}$

Data demonstrated in the table 4.2 illustrates that number of secondary branches $plant^{-1}$ was significantly higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that number of secondary branches $plant^{-1}$ was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of number of branches $plant^{-1}$ pointed out that it was increased with increasing age of crop and reached maximum at maturity. Increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$ increased the number of branches $plant^{-1}$ at all the dates of observation. Further, data signified that application of 70 kg $P_2O_5$ have shown higher number of branches $plant^{-1}$ at all dates of observation as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in number of secondary branches $plant^{-1}$ was up to 21.8 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of number secondary of branches $plant^{-1}$ pointed out that it was increased simultaneously with increasing age of crop and reached the maximum at maturity. Increasing levels of lime from 150, 300, 450 kg $ha^{-1}$ increased the number of secondary branches $plant^{-1}$ at all days of observation. Further, data signified that application of 450 kg lime have shown higher number of secondary branches $plant^{-1}$ at all dates of observation as compared to 150 kg lime but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in number of secondary branches $plant^{-1}$ was up to 13.4 per cent from 150 kg to 450 kg lime $ha^{-1}$.

### 4.1.3 NUMBER OF SILIQUAE PLANT$^{-1}$

Data presented in the table 4.3 indicates that number of siliquae $plant^{-1}$ was significantly higher in rest of the treatments as compared to the control.

Further addition of treatments revealed that number of siliquae $plant^{-1}$ was significantly higher at open plot as compared to rest of the treatments under agri-horti system.

**EFFECT OF PHOSPHORUS LEVEL**

Critical observation of data indicated that number of siliquae $plant^{-1}$ was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$ at harvest. Further, data indicated that number of siliquae $plant^{-1}$ was significantly higher by the application of 70 kg $P_2O_5$ as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, increase in number of siliquae was up to 6.6 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Critical observation of data indicated that number of siliquae $plant^{-1}$ was increased with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$ at harvest. Further, data showed that number of siliquae $plant^{-1}$ was significantly higher by the application of 450 kg lime as compared to 150 kg lime but was statistically at par with 300 kg lime $ha^{-1}$. However, the increase in number of siliquae $plant^{-1}$ was up to 8.6 per cent in 450 kg over 150 kg lime $ha^{-1}$.

### 4.1.4 DRY MATTER ACCUMULATION PLANT$^{-1}$ (g)

Data demonstrated in the table 4.4 illustrates that dry matter accumulation was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that dry matter accumulation was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of dry matter accumulation pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher dry matter accumulation as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$ at all dates of observation. However, the increment in dry matter accumulation was up to 6.6 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$

**EFFECT OF LIME LEVEL**

Close observation of data compiled of dry matter accumulation pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg ha$^{-1}$. Further, data signified that application of 450 kg lime have shown higher dry matter accumulation as compared to 150 kg lime but was statistically at par with 300 kg lime ha$^{-1}$ at all dates of observation. However, the increment in dry matter accumulation was up to 3.7 per cent from 150 kg to 450 kg lime ha$^{-1}$

## 4.2 YIELD ATTRIBUTES

### 4.2.1 LENGTH OF SILIQUA PLANT$^{-1}$

Data demonstrated in the table 4.3 illustrates that length of siliqua plant$^{-1}$ was significantly higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that length of siliqua plant$^{-1}$ was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data consisting of length of siliqua plant$^{-1}$ pointed out that it was increased with increasing application of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$ at harvest. Further, data signified that application of 70 kg $P_2O_5$ have shown higher length of siliqua plant$^{-1}$ as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. However, the increment in length of siliqua plant$^{-1}$ was up to 26 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data consisting of length of siliqua plant$^{-1}$ pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg ha$^{-1}$ at harvest. Further, data signified that application of 450 kg lime have shown higher length of siliqua plant$^{-1}$ at harvest as compared to 150 kg lime but was statistically at par with 300 kg lime ha$^{-1}$. However, the increment in length of siliqua plant$^{-1}$ was up to 14.9 per cent from 150 kg to 450 kg lime ha$^{-1}$

### 4.2.2 NUMBER OF SEEDS SILIQUA$^{-1}$

Data demonstrated in the table 4.3 illustrates that number of seeds siliqua$^{-1}$ was significantly higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that number of seeds siliqua$^{-1}$ was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of number of seeds siliqua$^{-1}$ pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher number of seeds siliqua$^{-1}$ as compared to 30 kg $P_2O_5$ but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. However, the increment in number of seeds siliqua$^{-1}$ was up to 26.4 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of number of seeds siliqua$^{-1}$ pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg ha$^{-1}$. Further, data signified that application of 450 kg lime have shown higher number of seeds siliqua$^{-1}$ as compared to 150 kg lime but was statistically at par with 300 kg lime ha$^{-1}$. However, the increment in number of seeds siliqua$^{-1}$ was up to 18.9 per cent from 150 kg to 450 kg lime ha$^{-1}$.

**4.2.3 SEED WEIGHT (g)**

Data demonstrated in the table 4.5 illustrates that seed weight was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that seed weight was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of seed weight pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher seed weight (4.87 g) as compared to 30 kg $P_2O_5$ (4.42 g) but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. However, the increment in seed weight was up to 10 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of seed weight pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher seed weight (4.9 g) as compared to 150 kg lime (4.43 g) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in seed weight was up to 10.6 per cent from 150 kg to 450 kg lime $ha^{-1}$.

### 4.2.4 SEED YIELD (kg $ha^{-1}$)

Data demonstrated in the table 4.5 illustrates that seed yield was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that seed yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of seed yield pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher seed yield (1391 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ (1242 kg $ha^{-1}$) but was at par with 50 kg $P_2O_5$ $ha^{-1}$. The increment in seed yield was up to 11.9 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of seed yield pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg lime $ha^{-1}$. Further, data signified that application of 450 kg lime $ha^{-1}$ have shown higher seed yield (1398 kg $ha^{-1}$) as compared to 150 kg $ha^{-1}$ (1285 kg $ha^{-1}$) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in seed yield was up to 8.7 per cent from 150 kg to 450 kg lime $ha^{-1}$.

### 4.2.5 STOVER YIELD

Data demonstrated in the table 4.5 illustrates that stover yield was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that stover yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of stover yield pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $P_2O_5$ $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher stover yield (5654 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ (4983 kg $ha^{-1}$) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in stover yield was up to 13.4 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of stover yield pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher stover yield (1399 kg $ha^{-1}$) as compared to 150 kg lime (1285 kg $ha^{-1}$) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in stover yield was up to 11.4 per cent from 150 kg lime to 450 kg lime $ha^{-1}$.

### 4.2.6 BIOLOGICAL YIELD

Data demonstrated in the table 4.6 illustrates that biological yield was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that biological yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of biological yield pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher biological yield (7045 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ $ha^{-1}$ (6226 kg $ha^{-1}$) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in biological yield was up to 6.3 per cent from 30 kg $P_2O_5$ to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of seed yield pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher stover yield (7079 kg $ha^{-1}$) as compared to 150 kg lime $ha^{-1}$ (6383 kg $ha^{-1}$). However, the increment in biological yield was up to 10.9 per cent from 150 kg lime to 450 kg lime $ha^{-1}$.

### 4.2.7 HARVEST INDEX

Critical examination of the data revealed that harvest index was not influenced by the treatment application.

## 4.3 QUALITY PARAMETERS

### 4.3.1 NITROGEN CONTENT IN SEED (%)

Data demonstrated in the table 4.7 illustrates that nitrogen content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that nitrogen content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

## EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of nitrogen content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have higher nitrogen content (3.4%) in seed as compared to 30 kg $P_2O_5$ (3.25%) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in nitrogen content was up to 4.6 per cent from 30 kg $P_2O_5$ to 70 kg $P_2O_5$ $ha^{-1}$.

## EFFECT OF LIME LEVEL

Close observation of data compiled of nitrogen content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher nitrogen content (3.39%) in seed as compared to 150 kg lime (3.28%) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in nitrogen content was up to 3.3 per cent from 150 kg to 450 kg lime $ha^{-1}$.

### 4.3.2 NITROGEN CONTENT IN STOVER (%)

Data demonstrated in the table 4.7 illustrates that nitrogen content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that nitrogen content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

## EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of nitrogen content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher nitrogen content (0.51%) in stover as compared to 30 kg $P_2O_5$ (0.44%) but was statistically at par with 50 kg

$P_2O_5$ ha$^{-1}$. However, the increment in nitrogen content was up to 18.6 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of nitrogen content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg ha$^{-1}$. Further, data signified that application of 450 kg lime have shown higher nitrogen content (0.51 %) in stover as compared to 150 kg lime (0.44%) but was statistically at par with 300 kg lime ha$^{-1}$. However, the increment in nitrogen content was up to 15.9 per cent from 150 kg to 450 kg lime ha$^{-1}$.

### 4.3.3 PHOSPHORUS CONTENT IN SEED (%)

Data demonstrated in the table 4.7 illustrates that phosphorus content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that phosphorus content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of phosphorus content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown there was higher phosphorus content (0.77%) in seed as compared to 30 kg $P_2O_5$ (0.68%) but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. However, the increment in phosphorus content was up to 13 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of phosphorus content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg ha$^{-1}$. Further, data signified that application of 450 kg lime have shown higher phosphorus content (0.35 %) in seed as compared to 150 kg lime (0.29%) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in phosphorus content was up 16.6 per cent from 150 kg to 450 kg lime $ha^{-1}$

### 4.3.4 PHOSPHORUS CONTENT IN STOVER (%)

Data demonstrated in the table 4.7 illustrates that phosphorus content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that phosphorus content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of phosphorus content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher phosphorus content (1.16%) in stover as compared to 30 kg (1.13%) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in phosphorus content was up to 28.5 per cent from 30 kg $P_2O_5$ to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of phosphorus content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher phosphorus content (1.14%) in stover as compared to 150 kg (1.1%) but was statistically at par with 300 kg lime $ha^{-1}$. However, the phosphorus content increment was up to 20.6 per cent from 150 kg lime to 450 kg lime $ha^{-1}$.

### 4.3.5 POTASSIUM CONTENT IN SEED (%)

Data demonstrated in the table 4.7 illustrates that potassium content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that potassium content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of potassium content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher potassium content (1.16%) as compared to 30 kg (1.13%) and 50 kg $P_2O_5$ $ha^{-1}$ (1.11%) but the differences could not meet the critical difference and hence it was proved to be non-significant.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of potassium content pointed out that it was increased with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher potassium content (1.14%) as compared to 150 kg (1.1%) and 300 kg lime $ha^{-1}$ (1.11%). However, the differences could not meet the critical differences and was proved to be non-significant.

### 4.3.6 POTASSIUM CONTENT IN STOVER (%)

Data demonstrated in the table 4.7 illustrates that potassium content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that potassium content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of potassium content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher potassium content (1.72%)

as compared to 30 kg $P_2O_5$ (1.69) and 50 kg $P_2O_5$ $ha^{-1}$ (1.68%) but the differences could not meet the critical differences hence was found to be insignificant.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of potassium content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher potassium content (1.69%) as compared to 150 kg (1.65%) and 300 kg lime (1.67%) but the differences could not meet the critical difference, hence it was found to be insignificant.

## 4.4 NUTRIENTS UPTAKE (kg $ha^{-1}$)

### 4.4.1 NITROGEN UPTAKE

Data demonstrated in the table 4.8 illustrates that nitrogen uptake was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that nitrogen uptake was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of nitrogen uptake pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown significantly higher nitrogen uptake both in seed (47.3 kg $ha^{-1}$) and stover (28.7 kg $ha^{-1}$) as compared to 30 $P_2O_5$ in seed (41.4 kg $ha^{-1}$) and stover (21.6 kg $ha^{-1}$) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in nitrogen uptake in seed and stover respectively was 14.2 and 32.8 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of nitrogen uptake pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher nitrogen uptake in seed (47.5 kg $ha^{-1}$) and stover (28.8 kg $ha^{-1}$) as compared to 150 kg lime ha $ha^{-1}$. However, nitrogen uptake in seed at 450 kg lime was found to be statistically at par with 300 kg lime $ha^{-1}$. The increment in nitrogen uptake in seed and stover respectively was 12.5 and 27.4 per cent from 150 kg to 450 kg lime $ha^{-1}$.

## 4.4.2 PHOSPHORUS UPTAKE

Data demonstrated in the table 4.9 illustrates that phosphorus uptake was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that phosphorus uptake was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of phosphorus uptake pointed out that it was increased significantly with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that 70 kg $P_2O_5$ have higher phosphorus uptake in seed (16 kg $ha^{-1}$) and stover (97.2 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ $ha^{-1}$ (12.4 kg $ha^{-1}$) in seed and (79 kg $ha^{-1}$) in stover. However, the increment in phosphorus uptake in seed and stover was 31.5 and 40.7 per cent from 30 kg $P_2O_5$ to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of phosphorus uptake pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher phosphorus uptake both in seed (15.9 kg $ha^{-1}$) and stover (96.13 kg $ha^{-1}$) as compared to 150 kg lime but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in phosphorus uptake in seed and stover was 26.9 and 29.2 per cent from 150 kg to 450 kg lime $ha^{-1}$

### 4.4.3 POTASSIUM UPTAKE

Data demonstrated in the table 4.10 illustrates that potassium content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that biological yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of pointed out that potassium uptake was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher potassium uptake in seed (16.0 kg $ha^{-1}$) and stover (12.4 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ in seed (12.4 $ha^{-1}$) and stover (79kg $ha^{-1}$) but 70 kg $P_2O_5$ was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in potassium uptake in seed and stover was 29 and 22.9 per cent from 30 kg $P_2O_5$ $ha^{-1}$ to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of potassium content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 Kg $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher potassium content in seed (15.9 kg $ha^{-1}$) and stover (96.13 kg $ha^{-1}$) as compared to 150 kg lime in seed (13.2 kg $ha^{-1}$) and stover (82.8 kg $ha^{-1}$) but it was observed that 450 kg lime was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in potassium content was up to 20 per cent in seed and 16 per cent in stover from 150 kg to 450 kg lime $ha^{-1}$.

## 4.5 OIL CONTENT (%)

Data demonstrated in the table 4.11 illustrates that oil content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that oil content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

### EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of oil content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg ha$^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher oil content (39%) as compared to 30 kg $P_2O_5$ (37.7%) but was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. However, the increment in oil content was up to 3.4 per cent from 30 kg to 70 kg $P_2O_5$ ha$^{-1}$.

### EFFECT OF LIME LEVEL

Close observation of data compiled of oil content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 Kg ha$^{-1}$. Further, data signified that application of 450 kg lime have shown higher oil content (38.8%) as compared to 150 kg lime (37.9%) but was statistically at par with 300 kg lime ha$^{-1}$. However, the increment in oil content was up to 2.3 per cent from 150 kg lime to 300 kg lime ha$^{-1}$.

## 4.6 OIL YIELD (kg ha$^{-1}$)

Data demonstrated in the table 4.11 illustrates that oil yield was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that oil yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

## EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of oil yield was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher oil yield (544 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ (469 kg $ha^{-1}$) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in oil yield was up to 15.9 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

## EFFECT OF LIME LEVEL

Close observation of data compiled of oil yield pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg lime $ha^{-1}$. Further, data signified that application of 450 kg lime have shown higher oil yield (543 kg $ha^{-1}$) as compared to 150 kg lime $ha^{-1}$ (488 kg $ha^{-1}$). However, the increment in oil yield was 11.2 per cent from 150 to 450 kg lime $ha^{-1}$.

## 4.7 PROTEIN CONTENT (%)

Data demonstrated in the table 4.12 illustrates that protein content was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that protein content was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

## EFFECT OF PHOSPHORUS LEVELS

Critical observation of data compiled of protein content pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher protein content (21.2%) as compared to 30 kg $P_2O_5$ (20.3%) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment in protein content was 4.4 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of potassium content pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime $ha^{-1}$ have shown higher protein content (21.2%) as compared to 150 kg lime (20.4%) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in protein content was 3.9 per cent from 150 kg to 450 kg lime $ha^{-1}$.

## 4.8 PROTEIN YIELD (kg $ha^{-1}$)

Data demonstrated in the table 4.12 illustrates that protein yield was higher in rest of the treatments as compared to the control.

Later on, addition of treatments signified that protein yield was significantly higher at open plot as compared to the plot laid in wood apple based agroforestry system.

**EFFECT OF PHOSPHORUS LEVELS**

Critical observation of data compiled of protein yield pointed out that it was increased with increasing levels of $P_2O_5$ from 30, 50, 70 kg $ha^{-1}$. Further, data signified that application of 70 kg $P_2O_5$ have shown higher protein yield (296 kg $ha^{-1}$) as compared to 30 kg $P_2O_5$ (252 kg $ha^{-1}$) but was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$. However, the increment was 16.9 per cent from 30 kg to 70 kg $P_2O_5$ $ha^{-1}$.

**EFFECT OF LIME LEVEL**

Close observation of data compiled of protein yield pointed out that it was increased simultaneously with increasing levels of lime from 150, 300, 450 kg $ha^{-1}$. Further, data signified that application of 450 kg lime $ha^{-1}$ have shown higher protein yield (297 kg $ha^{-1}$) as compared to 150 kg lime (252 kg $ha^{-1}$) but was statistically at par with 300 kg lime $ha^{-1}$. However, the increment in protein yield was 12.5 per cent from 150 kg to 450 kg lime $ha^{-1}$.

## 4.9 RELATIVE ECONOMICS

Research finding may be useful from academic point of view but it cannot be practiced by farmers unless these findings are economically sustainable and beneficial for them.

The economic analysis includes the cost of cultivation, gross income, benefit-cost ratio for different treatment combinations.

### 4.9.1 COST OF CULTIVATION (Rs $ha^{-1}$)

Cost of different agricultural operations starting from land preparation to harvesting such as irrigation, weeding, pruning was summed up to find out common cost of cultivation. Treatment cost was estimated separately which was added with common cost of cultivation to calculate total cost of cultivation. It was observed that total cost of cultivation was maximum for 50 $P_2O_5$ and 450 kg lime $ha^{-1}$ whereas minimum cost of cultivation was for the control treatment (no lime, no phosphorus).

### 4.9.2 GROSS INCOME (Rs $ha^{-1}$)

Application of different levels of $P_2O_5$ have shown variation in gross income. It was observed that higher gross income (Rs 75999 $ha^{-1}$) was obtained from highest level of $P_2O_5$ (70 kg $ha^{-1}$) over medium (50 kg $ha^{-1}$) and lower level (30 kg $ha^{-1}$) however, the highest level of $P_2O_5$ (70 kg $ha^{-1}$) was statistically at par with medium level (50 kg $ha^{-1}$).

Due to different levels of lime, higher gross income (Rs 76409 $ha^{-1}$) was obtained from highest level of lime (450 kg $ha^{-1}$) as compared to 300 kg and 150 kg lime $ha^{-1}$. However, the difference between 450 kg and 300 kg lime $ha^{-1}$ could not meet the critical difference and was found to be non-significant.

Among different treatment combinations, 50 kg $P_2O_5$ $ha^{-1}$ with 450 kg lime $ha^{-1}$ have shown maximum gross income (Rs 139646 $ha^{-1}$) followed by 50 kg $P_2O_5$ with 300 kg lime $ha^{-1}$ (Rs 134190 $ha^{-1}$). Minimum gross income was recorded in the treatment combination of 30 kg $P_2O_5$ with 150 kg lime $ha^{-1}$ (Rs 119315 $ha^{-1}$).

### 4.9.3 NET RETURN (Rs $ha^{-1}$)

Different levels of $P_2O_5$ have shown variation in net return. Maximum net return was found in 50 kg $P_2O_5$ $ha^{-1}$ (Rs 39297 $ha^{-1}$) and minimum net return was found to be in 30 kg $P_2O_5$ $ha^{-1}$ (Rs 32266 $ha^{-1}$). However, the difference between 70 kg $P_2O_5$ and 50 kg $P_2O_5$ $ha^{-1}$ was found to be statistically at par.

Different levels of lime have shown variation in net return. Maximum net return was found at 450 kg lime $ha^{-1}$(Rs 36641 $ha^{-1}$) and minimum net return was found to be at 150 kg lime $ha^{-1}$ (Rs 36630 $ha^{-1}$). However, the difference between 450 kg lime and 150 kg lime $ha^{-1}$ was found to statistically at par.

Among different treatment combinations maximum net return was found to be at 50 kg $P_2O_5$ $ha^{-1}$ with 450 kg lime $ha^{-1}$ (Rs 99914 $ha^{-1}$).

### 4.9.4 BENEFIT-COST RATIO

Different levels of $P_2O_5$ have shown variation in cost benefit ratio. Application of 50 kg $P_2O_5$ $ha^{-1}$ (1.22) have shown higher benefit cost ratio as compared to 70 kg $P_2O_5$ $ha^{-1}$ and 30 kg $P_2O_5$ $ha^{-1}$.

Due to different levels of lime, it was noticed that higher benefit cost ratio was obtained by lime at 300 kg $ha^{-1}$ (2.6) as compared to 450 and 150 kg lime $ha^{-1}$.

**Table 4.1: Effect of phosphorus and lime levels on height of Indian mustard under wood apple based agri-horti system**

| Treatment | Plant height (cm) | | | |
|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | At harvest |
| Levels of phosphorus (kg $P_2O_5$ $ha^{-1}$) | | | | |
| 30 | 12.6 | 139 | 145 | 147 |
| 50 | 13.9 | 158 | 164 | 165 |
| 70 | 14.5 | 159 | 169 | 169 |
| SEm± | 0.55 | 3.69 | 3.45 | 1.85 |
| CD (P=0.05) | 1.15 | 7.76 | 7.24 | 3.89 |
| Levels of lime (kg $ha^{-1}$) | | | | |
| 150 | 12.5 | 142 | 152 | 155 |
| 300 | 13.9 | 155 | 161 | 162 |
| 450 | 14.7 | 158 | 166 | 166 |
| SEm± | 0.55 | 3.69 | 3.45 | 1.85 |
| CD (P=0.05) | 1.15 | 7.76 | 7.24 | 3.89 |
| Control (No phosphorus and no lime) | 9.23 | 111 | 113 | 114 |
| Rest of the treatment | 13.2 | 149 | 155 | 156 |
| SEm± | 0.7 | 4.88 | 4.56 | 8.84 |
| CD (P=0.05) | 2.14 | 14.5 | 13.5 | 2.97 |
| Open area plot# | 14.6 | 164 | 169 | 169 |
| Rest of the treatment | 13.2 | 149 | 155 | 156 |
| SEm± | 0.69 | 4.47 | 4.36 | 7.09 |
| CD (P=0.05) | NS | 13.2 | 2.9 | 2.39 |
| Phosphorus× Lime | NS | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime $ha^{-1}$

NS: Non-Significant

**Table 4.2: Effect of phosphorus and lime levels on number of secondary branches of Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Number of secondary branches plant$^{-1}$** | | |
|---|---|---|---|
| | **60 DAS** | **90 DAS** | **At harvest** |
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | |
| 30 | 8.67 | 14.5 | 13.3 |
| 50 | 11.0 | 16.5 | 15.6 |
| 70 | 11.7 | 17.0 | 16.2 |
| SEm± | 0.55 | 0.56 | 0.60 |
| CD (P=0.05) | 1.15 | 1.19 | 1.26 |
| Levels of lime (kg ha$^{-1}$) | | | |
| 150 | 9.22 | 15.2 | 14.1 |
| 300 | 10.6 | 16.1 | 15.1 |
| 450 | 11.6 | 16.9 | 16.0 |
| SEm± | 0.55 | 0.56 | 0.60 |
| CD (P=0.05) | 1.15 | 1.19 | 1.26 |
| Control (No phosphorus and no lime) | 6.0 | 12.7 | 11.3 |
| Rest of the treatment | 9.83 | 15.6 | 14.5 |
| SEm± | 0.73 | 0.77 | 0.86 |
| CD (P=0.05) | 2.16 | 2.28 | 2.54 |
| OPEN | 12.0 | 17.7 | 16.7 |
| Rest of the treatment | 9.83 | 15.5 | 14.5 |
| SEm± | 0.39 | 0.75 | 0.80 |
| CD (P=0.05) | 1.15 | 2.22 | 2.36 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant

**Table 4.3: Effect of phosphorus and lime levels on number of siliquae plant$^{-1}$, length of siliqua, seeds siliqua$^{-1}$ of Indian mustard under wood apple based agri-horti system.**

| **Treatment** | **Number of siliquae plant$^{-1}$** | **Length of siliqua (cm)** | **Seeds siliqua$^{-1}$** |
|---|---|---|---|
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | |
| 30 | 212 | 4.37 | 10.6 |
| 50 | 224 | 5.27 | 12.7 |
| 70 | 226 | 5.51 | 13.4 |
| SEm± | 2.55 | 0.21 | 0.38 |
| CD (P=0.05) | 5.35 | 0.25 | 0.79 |
| Levels of lime (kg ha$^{-1}$) | | | |
| 150 | 209 | 4.63 | 11.1 |
| 300 | 225 | 5.19 | 12.4 |
| 450 | 227 | 5.32 | 13.2 |
| SEm± | 2.55 | 0.12 | 0.38 |
| CD (P=0.05) | 5.35 | 0.25 | 0.79 |
| Control (No phosphorus and no lime) | 197 | 3.50 | 8.67 |
| Rest of the treatment | 218 | 4.82 | 11.7 |
| SEm± | 3.38 | 0.16 | 0.58 |
| CD (P=0.05) | 10.04 | 0.47 | 1.74 |
| Open area plot# | 230 | 5.50 | 14.0 |
| Rest of the treatment | 218 | 4.82 | 11.7 |
| SEm± | 3.37 | 0.16 | 0.50 |
| CD (P=0.05) | 10.0 | 0.46 | 1.48 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant.

**Table 4.4: Effect of phosphorus and lime levels on dry matter accumulation of Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Dry matter accumulation (g plant$^{-1}$)** | | | |
|---|---|---|---|---|
| | **30 DAS** | **60 DAS** | **90 DAS** | **At harvest** |
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | | |
| 30 | 0.96 | 19.3 | 56.7 | 57.5 |
| 50 | 1.20 | 22.5 | 58.7 | 60.1 |
| 70 | 1.24 | 22.7 | 59.5 | 61.3 |
| SEm± | 0.04 | 0.33 | 0.54 | 0.66 |
| CD (P=0.05) | 0.07 | 0.69 | 1.13 | 1.39 |
| Levels of lime (kg ha$^{-1}$) | | | | |
| 150 | 1.08 | 20.3 | 57.2 | 58.4 |
| 300 | 1.16 | 21.9 | 58.3 | 59.9 |
| 450 | 1.17 | 22.3 | 59.3 | 60.6 |
| SEm± | 0.04 | 0.33 | 0.54 | 0.66 |
| CD (P=0.05) | 0.07 | 0.69 | 1.13 | 1.39 |
| Control (No phosphorus and no lime) | 0.84 | 18.1 | 51.1 | 52.1 |
| Rest of the treatment | 1.08 | 20.9 | 57.7 | 58.8 |
| SEm± | 0.04 | 0.47 | 0.69 | 0.87 |
| CD (P=0.05) | 0.11 | 1.40 | 2.04 | 2.60 |
| Open area plot# | 1.09 | 23.1 | 58.0 | 60.6 |
| Rest of the treatment | 1.08 | 20.9 | 57.7 | 58.8 |
| SEm± | 0.05 | 0.44 | 0.71 | 0.68 |
| CD (P=0.05) | NS | 1.30 | NS | NS |
| Phosphorus× Lime | NS | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant

**Table 4.5: Effect of phosphorus and lime levels on seed weight, seed yield, stover yield of Indian mustard under wood apple based agri-horti system**

| Treatment | Seed weight (g) | Seed yield ($kg\ ha^{-1}$) | Stover yield ($kg\ ha^{-1}$) |
|---|---|---|---|
| Levels of phosphorus ($kg\ P_2O_5\ ha^{-1}$) | | | |
| 30 | 4.42 | 1243 | 4984 |
| 50 | 4.74 | 1388 | 5631 |
| 70 | 4.87 | 1391 | 5654 |
| SEm± | 0.12 | 41.5 | 101 |
| CD (P=0.05) | 0.25 | 87.2 | 214 |
| Levels of lime ($kg\ ha^{-1}$) | | | |
| 150 | 4.42 | 1286 | 5097 |
| 300 | 4.74 | 1338 | 5491 |
| 450 | 4.87 | 1398 | 5680 |
| SEm± | 0.12 | 41.5 | 102 |
| CD (P=0.05) | 0.25 | 87.2 | 214 |
| Control (No phosphorus and no lime) | 3.97 | 1015 | 4107 |
| Rest of the treatment | 4.58 | 1315 | 5307 |
| SEm± | 0.15 | 41.1 | 111 |
| CD (P=0.05) | 0.45 | 123 | 323 |
| Open area plot# | 4.63 | 1468 | 5798 |
| Rest of the treatment | 4.58 | 1315 | 5307 |
| SEm± | 0.16 | 36.45 | 111 |
| CD (P=0.05) | 0.47 | 109 | 329 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime $ha^{-1}$

NS: Non-Significant

**Table 4.6: Effect of phosphorus and lime levels on biological yield and harvest index of Indian mustard under wood apple based agri-horti system**

| Treatment | Biological yield (kg ha$^{-1}$) | Harvest index (%) |
|---|---|---|
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | |
| 30 | 6626 | 20.0 |
| 50 | 7019 | 19.7 |
| 70 | 7045 | 19.8 |
| SEm± | 103 | 0.46 |
| CD (P=0.05) | 216 | 0.96 |
| Levels of lime (kg ha$^{-1}$) | | |
| 150 | 6383 | 20.1 |
| 300 | 6829 | 19.6 |
| 450 | 7079 | 19.7 |
| SEm± | 103 | 0.46 |
| CD (P=0.05) | 217 | 0.96 |
| Control (No phosphorus and no lime) | 5122 | 19.9 |
| Rest of the treatment | 6623 | 19.9 |
| SEm± | 136 | 0.61 |
| CD (P=0.05) | 405 | 1.81 |
| Open area plot# | 7236 | 20.1 |
| Rest of the treatment | 6623 | 19.9 |
| SEm± | 111 | 0.49 |
| CD (P=0.05) | 333 | 1.46 |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant

**Table 4.7: Effect of phosphorus and lime levels on nutrient content of Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Content in percent (%)** | | | | | |
|---|---|---|---|---|---|---|
| | **Nitrogen content in seed** | **Nitrogen content in stover** | **Phosphorus content in seed** | **Phosphorus content in stover** | **Potassium content in seed** | **Potassium content in stover** |
| Levels of phosphorus (kg $P_2O_5$ $ha^{-1}$) | | | | | | |
| 30 | 3.25 | 0.43 | 0.68 | 0.28 | 1.13 | 1.69 |
| 50 | 3.36 | 0.48 | 0.74 | 0.34 | 1.11 | 1.68 |
| 70 | 3.40 | 0.51 | 0.77 | 0.36 | 1.16 | 1.72 |
| SEm± | 0.03 | 0.02 | 0.02 | 0.01 | 0.03 | 0.02 |
| CD (P=0.05) | 0.06 | 0.04 | 0.05 | 0.02 | NS | NS |
| Levels of lime (kg $ha^{-1}$) | | | | | | |
| 150 | 3.28 | 0.44 | 0.66 | 0.29 | 1.10 | 1.65 |
| 300 | 3.34 | 0.47 | 0.76 | 0.33 | 1.11 | 1.67 |
| 450 | 3.39 | 0.51 | 0.77 | 0.35 | 1.14 | 1.69 |
| Sem± | 0.03 | 0.02 | 0.02 | 0.01 | 0.03 | 0.02 |
| CD (P=0.05) | 0.06 | 0.04 | 0.05 | 0.02 | NS | NS |
| Control (No phosphorus and no lime) | 3.20 | 0.30 | 0.49 | 0.24 | 0.99 | 1.52 |
| Rest of the treatment | 3.39 | 0.46 | 0.71 | 0.31 | 1.05 | 1.63 |
| Sem± | 0.02 | 0.02 | 0.03 | 0.01 | 0.04 | 0.03 |
| CD (P=0.05) | 0.04 | 0.07 | 0.10 | 0.03 | NS | NS |
| Open area plot# | 3.43 | 0.50 | 0.77 | 0.35 | 1.13 | 1.68 |
| Rest of the treatment | 3.39 | 0.46 | 0.71 | 0.31 | 1.05 | 1.63 |
| Sem± | 0.02 | 0.02 | 0.03 | 0.01 | 0.04 | 0.03 |
| CD (P=0.05) | 0.04 | 0.07 | 0.10 | 0.03 | NS | NS |
| Phosphorus× Lime | NS | NS | NS | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime $ha^{-1}$

NS: Non-Significant

**Table 4.8 Effect of phosphorus and lime levels on nitrogen uptake by Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Nitrogen uptake (kg ha$^{-1}$)** | | |
|---|---|---|---|
| | **Uptake by seed** | **Uptake by stover** | **Total Uptake** |
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | |
| 30 | 41.4 | 21.6 | 62.0 |
| 50 | 46.7 | 27.3 | 74.0 |
| 70 | 47.3 | 28.7 | 76.0 |
| SEm± | 1.01 | 1.40 | 1.77 |
| CD (P=0.05) | 2.12 | 2.94 | 3.72 |
| Levels of lime (kg ha$^{-1}$) | | | |
| 150 | 42.2 | 22.6 | 64.8 |
| 300 | 44.7 | 26.2 | 70.9 |
| 450 | 47.5 | 28.8 | 76.3 |
| SEm± | 1.01 | 1.40 | 1.77 |
| CD (P=0.05) | 2.12 | 2.94 | 3.72 |
| Control (No phosphorus and no lime) | 30.7 | 12.3 | 59.4 |
| Rest of the treatment | 43.5 | 24.4 | 68.0 |
| SEm± | 1.33 | 1.31 | 1.66 |
| CD (P=0.05) | 3.96 | 3.89 | 4.93 |
| Open area plot# | 50.4 | 28.2 | 79.1 |
| Rest of the treatment | 43.5 | 24.4 | 68.0 |
| SEm± | 1.30 | 1.43 | 1.80 |
| CD (P=0.05) | 3.86 | NS | 5.34 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant

**Table 4.9: Effect of phosphorus and lime levels on phosphorus uptake by Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Phosphorus uptake (kg ha$^{-1}$)** | | |
|---|---|---|---|
| | **Uptake by seed** | **Uptake by stover** | **Total uptake** |
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | |
| 30 | 8.42 | 14.5 | 22.9 |
| 50 | 10.3 | 19.0 | 29.3 |
| 70 | 11.0 | 20.5 | 31.2 |
| SEm± | 0.30 | 0.83 | 0.90 |
| CD (P=0.05) | 0.62 | 1.15 | 1.88 |
| Levels of lime (kg ha$^{-1}$) | | | |
| 150 | 8.47 | 15.5 | 24.0 |
| 300 | 10.15 | 18.4 | 28.6 |
| 450 | 10.75 | 20.0 | 30.8 |
| SEm± | 0.30 | 0.83 | 0.90 |
| CD (P=0.05) | 0.62 | 1.75 | 1.88 |
| Control (No phosphorus and no lime) | 5.00 | 9.17 | 14.77 |
| Rest of the treatment | 9.37 | 16.7 | 26.0 |
| SEm± | 0.39 | 0.78 | 0.84 |
| CD (P=0.05) | 1.17 | 2.31 | 2.49 |
| Open area plot# | 11.30 | 20.47 | 31.7 |
| Rest of the treatment | 9.37 | 16.7 | 26.0 |
| SEm± | 0.36 | 0.79 | 0.89 |
| CD (P=0.05) | 1.08 | 2.34 | 2.64 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant

**Table 4.10: Effect of phosphorus and lime levels on potassium uptake by Indian mustard under wood apple based agri-horti system.**

| Treatment | Potassium uptake (kg $ha^{-1}$) | | |
|---|---|---|---|
| | Uptake by seed | Uptake by stover | Total uptake |
| Levels of phosphorus (kg $P_2O_5$ $ha^{-1}$) | | | |
| 30 | 12.4 | 79.0 | 91.5 |
| 50 | 15.4 | 94.7 | 110 |
| 70 | 16.0 | 97.2 | 113 |
| SEm± | 0.58 | 2.19 | 2.32 |
| CD (P=0.05) | 1.21 | 4.60 | 4.88 |
| Levels of lime (kg $ha^{-1}$) | | | |
| 150 | 13.2 | 82.8 | 96.1 |
| 300 | 14.8 | 92.0 | 107 |
| 450 | 15.9 | 96.1 | 112 |
| SEm± | 0.58 | 2.19 | 2.32 |
| CD (P=0.05) | 1.21 | 4.60 | 4.88 |
| Control (No phosphorus and no lime) | 8.45 | 61.0 | 69.6 |
| Rest of the treatment | 13.9 | 86.91 | 100 |
| SEm± | 0.76 | 2.90 | 3.48 |
| CD (P=0.05) | 2.26 | 8.60 | 10.3 |
| Open area plot# | 16.6 | 97.5 | 114 |
| Rest of the treatment | 13.9 | 86.9 | 100 |
| SEm± | 0.69 | 2.59 | 3.08 |
| CD (P=0.05) | 2.04 | 7.69 | 9.14 |
| Phosphorus× Lime | NS | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime $ha^{-1}$

NS: Non-Significant

**Table 4.11: Effect of phosphorus and lime levels on oil content and oil yield of Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Oil content (%)** | **Oil yield (kg ha$^{-1}$)** |
|---|---|---|
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | |
| 30 | 37.7 | 469 |
| 50 | 38.5 | 534 |
| 70 | 39.0 | 544 |
| SEm± | 0.30 | 12.5 |
| CD (P=0.05) | 0.64 | 26.1 |
| Levels of lime (kg ha$^{-1}$) | | |
| 150 | 37.9 | 488 |
| 300 | 38.5 | 515 |
| 450 | 38.8 | 543 |
| SEm± | 0.30 | 12.4 |
| CD (P=0.05) | 0.64 | 26.1 |
| Control (No phosphorus and no lime) | 36.6 | 372 |
| Rest of the treatment | 38.0 | 501 |
| SEm± | 0.40 | 16.4 |
| CD (P=0.05) | 1.19 | 48.9 |
| Open area plot# | 38.8 | 570 |
| Rest of the treatment | 38.0 | 501 |
| SEm± | 0.17 | 14.6 |
| CD (P=0.05) | 0.52 | 43.5 |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS: Non-Significant.

**Table 4.12: Effect of phosphorus and lime levels on protein content and protein yield of Indian mustard under wood apple based agri-horti system**

| Treatment | Protein content (%) | Protein yield (kg $ha^{-1}$) |
|---|---|---|
| Levels of phosphorus (kg $P_2O_5$ $ha^{-1}$) | | |
| 30 | 20.3 | 252 |
| 50 | 21.0 | 291 |
| 70 | 21.2 | 296 |
| SEm± | 0.18 | 4.45 |
| CD (P=0.05) | 0.39 | 9.35 |
| Levels of lime (kg $ha^{-1}$) | | |
| 150 | 20.4 | 263 |
| 300 | 20.9 | 279 |
| 450 | 21.2 | 297 |
| SEm± | 0.18 | 4.45 |
| CD (P=0.05) | 0.39 | 9.35 |
| Control (No phosphorus and no lime) | 18.96 | 192 |
| Rest of the treatment | 20.6 | 272 |
| SEm± | 0.24 | 5.89 |
| CD (P=0.05) | 0.72 | 17.5 |
| Open area plot# | 21.4 | 315 |
| Rest of the treatment | 20.6 | 272 |
| SEm± | 0.22 | 5.74 |
| CD (P=0.05) | 0.66 | 17.0 |
| Phosphorus×Lime | NS | NS |

#Fertilized with 90, 50, 30 kg NPK and 300 kg Lime $ha^{-1}$

NS: Non-Significant

**Table 4.13: Effect of phosphorus and lime levels on economics of Indian mustard under wood apple based agri-horti system**

| **Treatment** | **Cost of cultivation (₹ ha$^{-1}$)** | **Gross income (₹ ha$^{-1}$)** | **Net return (₹ ha$^{-1}$)** | **Benefit: cost** |
|---|---|---|---|---|
| Levels of phosphorus (kg $P_2O_5$ ha$^{-1}$) | | | | |
| 30 | 35491 | 67756 | 32266 | 0.95 |
| 50 | 36523 | 75819 | 39297 | 1.22 |
| 70 | 37658 | 75999 | 38342 | 1.18 |
| SEm± | ------- | 1285 | 1464 | 0.07 |
| CD (P=0.05) | ------- | 2698.95 | 3075.44 | 0.15 |
| Levels of lime (kg ha$^{-1}$) | | | | |
| 150 | 33347 | 69978 | 36630 | 1.12 |
| 300 | 36557 | 73189 | 36632 | 2.60 |
| 450 | 39767 | 76409 | 36641 | 1.14 |
| SEm± | ------ | 1285 | 1464 | 0.07 |
| CD (P=0.05) | ------- | 2699 | 3075 | 0.15 |
| Control (No phosphorus and no lime) | 26904 | 55438 | 28534 | 1.07 |
| Rest of the treatment | 36007 | 71788 | 35781 | 1.09 |
| SEm± | ------ | 1936.50 | 1936.50 | 0.09 |
| CD (P=0.05) | -------- | 5754 | 5754 | 0.28 |
| Phosphorus× Lime | NS | NS | NS | NS |

[#]Fertilized with 90, 50, 30 kg NPK and 300 kg Lime ha$^{-1}$

NS : Non-Significant.

**Table 4.14 : Effect of phosphorus and lime levels on economics of mustard**

| S.No. | Treatment | Cost of cultivation (₹ $ha^{-1}$)# | Gross income (₹ $ha^{-1}$) | | | | Net return (₹ $ha^{-1}$) | Benefit : cost |
|---|---|---|---|---|---|---|---|---|
| | | | Seed | Stover | Wood apple (Fruit) | Total | | |
| 1. | $P_2O_5$ (30 kg $ha^{-1}$+Lime (150 kg $ha^{-1)}$ | **32281** | 55350 | 8885 | 55080 | 119,315 | 87034 | 2.7 |
| 2. | $P_2O_5$ (30 kg $ha^{-1}$+Lime (300 kg $ha^{-1)}$ | **35481** | 56017 | 9973 | 55080 | 121,070 | 85589 | 2.4 |
| 3. | $P_2O_5$ (30 kg $ha^{-1}$+Lime (450 kg $ha^{-1)}$ | **38701** | 62000 | 11044 | 55080 | 128,124 | 89423 | 2.3 |
| 4. | $P_2O_5$ (50 kg $ha^{-1}$+Lime (150 kg $ha^{-1)}$ | **33312** | 65177 | 11496 | 55080 | 131,753 | 98441 | 3.0 |
| 5. | $P_2O_5$ (50 kg $ha^{-1}$+Lime (300 kg $ha^{-1)}$ | **36522** | 67518 | 11592 | 55080 | 134,190 | 97668 | 2.7 |
| 6. | $P_2O_5$ (50 kg $ha^{-1}$+Lime (450 kg $ha^{-1)}$ | **39732** | 71455 | 13111 | 55080 | 139,646 | 99914 | 2.5 |
| 7. | $P_2O_5$ (70 kg $ha^{-1}$+Lime (150 kg $ha^{-1)}$ | **34447** | 59287 | 10710 | 55080 | 125,077 | 90630 | 1.5 |
| 8. | $P_2O_5$ (70 kg $ha^{-1}$+Lime (300 kg $ha^{-1)}$ | **37658** | 66650 | 11478 | 55080 | 133,208 | 95550 | 2.5 |
| 9. | $P_2O_5$ (70 kg $ha^{-1}$+Lime (450 kg $ha^{-1)}$ | **40868** | 67735 | 11665 | 55080 | 134,480 | 93612 | 2.3 |
| 10. | Control | **26904** | 47224 | 8213 | 55080 | 110,517 | 83613 | 3.1 |
| 11. | Open $P_2O_5$ (50 kg $ha^{-1}$+Lime (300 kg $ha^{-1)}$ | **36523** | 68262 | 11590 | 0 | 79852 | 43329 | 1.2 |

# Included common cost of cultivation of mustard under wood apple based on agri-horti system (₹ 25325 $ha^{-1}$)
Cost of seed = ₹ 46.5 $kg^{-1}$, Cost of stover = ₹ $kg^{-1}$

*Chapter V*

# DISCUSSION

The present experiment entitled "Effect of phosphorus and lime levels on Indian mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system" was carried out during winter (*Rabi*) season of 2019-2020 at Agricultural Research Farm of Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur district, Uttar Pradesh. This chapter includes evaluation of important characteristics observed in respect of cause and effect relationship during the experiment. Most important parameter to be noticed in research related to agriculture is the produce of crop. It is the harvested production per unit of harvested area for crop products such as seed yield, stover yield, oil yield etc. Yield per unit area is the indication of to what extent the applied nutrients and surrounding environment was beneficial, which in turn is the cumulative function of yield plant$^{-1}$. Yield and growth parameters are directly influenced by carrying heredity, but the role of external fertilizers, cultural practices and surrounding environment cannot be neglected as they also contribute towards the growth and development of plants.

The findings have been discussed with logical reasoning, their cause and effect after remarks on the weather situation during the crop period. Weather situation in an agroforestry system is important to be discussed because apart from factors of different fertility levels, the interaction of respective component crop and its somewhat symbiotic cum parasitic relationship with environment is an important factor. For better understanding of data recorded, graphical representation has been exhibited wherever necessary.

## 5.1 EFFECT OF WEATHER CONDITIONS ON GROWTH AND YIELD OF MUSTARD

Relation of crop with environmental factor is an important factor as it affects the growth and yield of crops. Thus concluding a result of agriculture experiment without considering weather conditions would be biased and incomplete. The variation in weather parameters has shown fluctuation on crop growth. Each crop has its own cardinal point of relative humidity, air temperature, vapour pressure and hours of sunshine to achieve the yield potential. Extreme fluctuation from the optimum value will retard the growth, development and yield of crop. The weather factors viz., rainfall, temperature and relative humidity recorded during crop duration of the present experimentation are shown in Table 3.1. The meteorological data recorded during the cropping period shows that the weekly maximum temperature (30°C) was observed in the month of March while the minimum temperature (07°C) was observed in the month of December.

## 5.2 EFFECT OF PHOSPHORUS

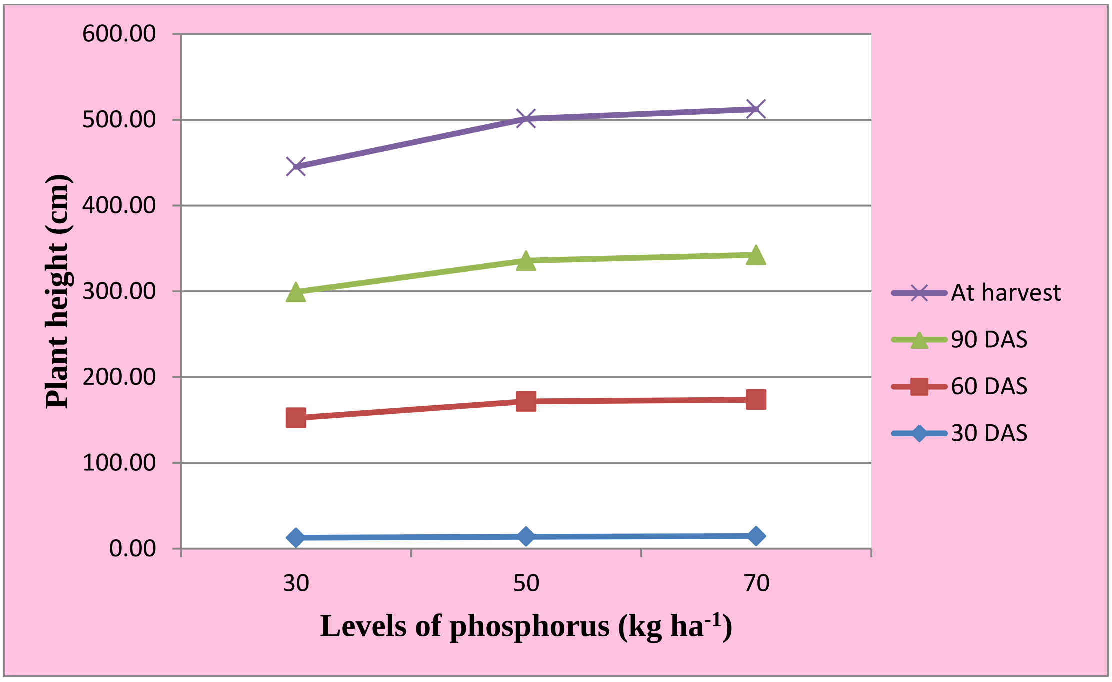
### 5.2.1 EFFECT OF PHOSPHORUS ON YIELD ATTRIBUTES

The effect of varying levels of phosphorus can be seen in growth and yield parameters of mustard. Mean of seed and stover yield presented in table 4.5 shows that it was significantly influenced by the application of different levels of phosphorus. Increasing levels of phosphorus (30, 50, 70 kg $ha^{-1}$) have significantly increased the seed and stover yield. The higher seed yield (1391 kg $ha^{-1}$) was obtained by the application of 70 kg $P_2O_5$ $ha^{-1}$ over the control (1015 kg $ha^{-1}$) (no phosphorus, no lime) but it was statistically at par with 50 kg $P_2O_5$ $ha^{-1}$, in the same way, the maximum stover yield (5654 kg $ha^{-1}$) was also obtained at 70 kg $P_2O_5$ $ha^{-1}$ over the control (4107 kg $ha^{-1}$) but it was statistically at par with 50 kg $ha^{-1}$. The probable reason for increase in yield might be due to increase in seeds $siliqua^{-1}$, number of siliquae $plant^{-1}$, seed weight, siliqua length and other growth attributes. The significant increment in economic yields would be due to increment in growth and yield attributes of the crop. Increasing levels of phosphorus $ha^{-1}$ would have influenced the growth because the element "phosphorus" is vital for energy transformation reactions and respiration processes. Increase in seed weight by the application of increasing levels of $P_2O_5$ might be due to the contribution of phosphorus in bold seed formation by increasing the size of the seed. It also helps in establishment of healthier stocks and root system. It is important for ripening of fruit and seeds. Phosphorus plays a major role in photosynthesis process, mobility of nutrients and transformation of genetic characteristics. It also influences utilization of nitrogen. Relatable findings were also noticed by Mani *et al*. (2006) and Nath *et al*. (2018).

### 5.2.2 EFFECT OF PHOSPHORUS ON GROWTH PARAMETERS

Data recorded of the present experiment evidenced that growth parameters such as plant height, number of secondary branches, siliqua length (cm) and dry matter accumulation were affected by the levels of phosphorus (30, 50, 70 kg $P_2O_5$ $ha^{-1}$). It was observed that the plant height (169 cm) and secondary branches (16) at harvest, siliqua length (5.51 cm) and dry matter accumulation (61.3 g) at harvest was recorded as highest at 70 kg $P_2O_5$ $ha^{-1}$. It was further, observed that results obtained at 50 kg was at par with 70 kg $P_2O_5$ $ha^{-1}$ whereas the difference between 70 and 30 kg $P_2O_5$ $ha^{-1}$ was found to be significant. Increment in growth parameters with increasing phosphorus levels might be due its contribution in enhancing the growth activity, setting of pods as phosphorus is responsible for stimulation of flowering and seed formation. Since, the soil was low in phosphorus, its application through fertilizer would have helped in increasing the availability of phosphorus to the crop. Phosphorus is also an essential constituent of nucleic acid, lipoprotein membrane of cell and many coenzymes responsible for energy transfer reaction in cell metabolism. It improves flower formation, promotes in uniformity of crops, increase disease resistance which would have overall improved the quality of crop (Yadav *et al*, 2014).

Similarly, experiment carried out by Birle, 2011 to study the effect of phosphorus and zinc on yield and chemical composition of mustard grown on sodic soil revealed that the plant height, siliquae per plant, seeds per siliqua and test weight of seed was significantly increased due to the application of 60 kg $P_2O_5$ $ha^{-1}$ over the control.



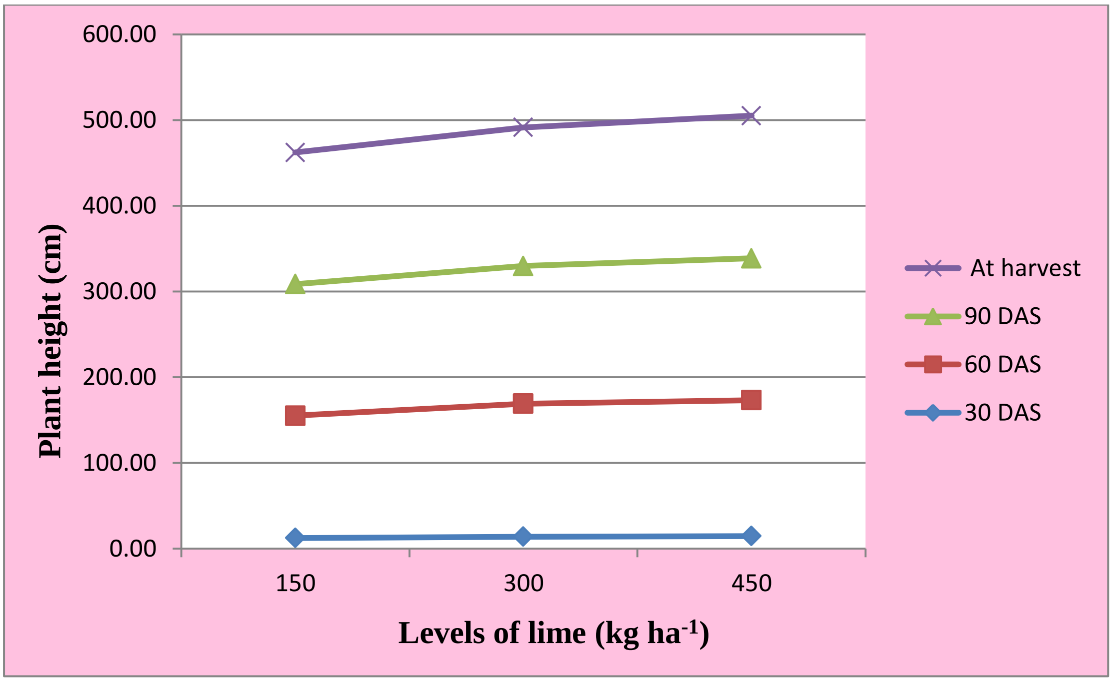
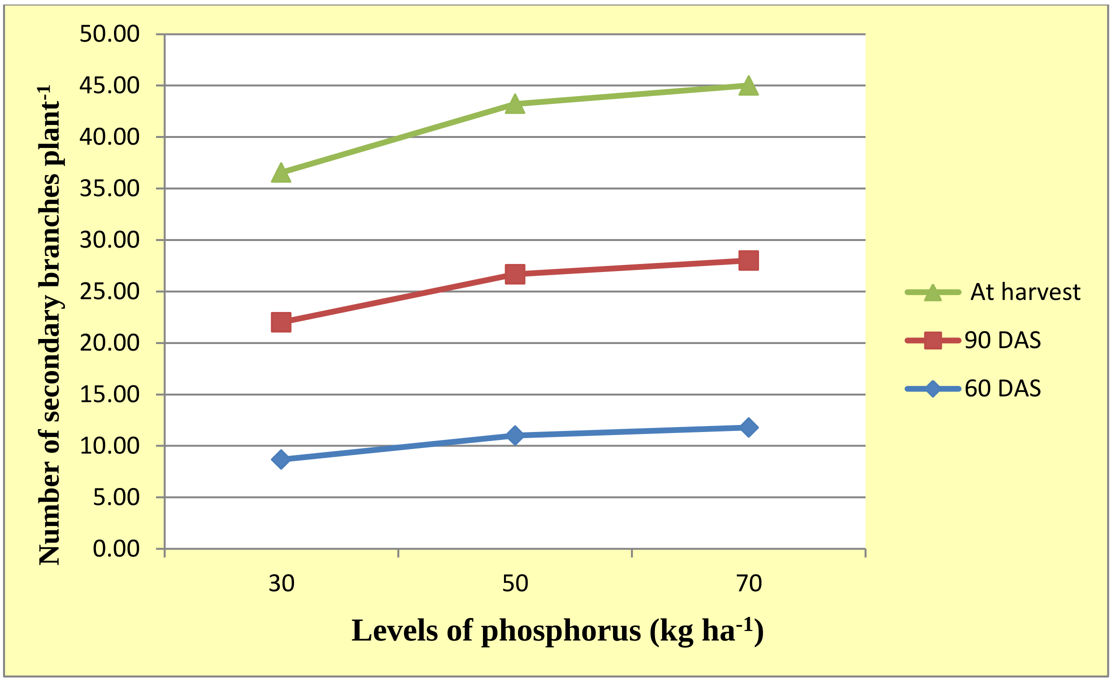




**Fig. 5.1: Effect of phosphorus and lime levels on plant height of Indian mustard under wood apple based agri-horti system.**



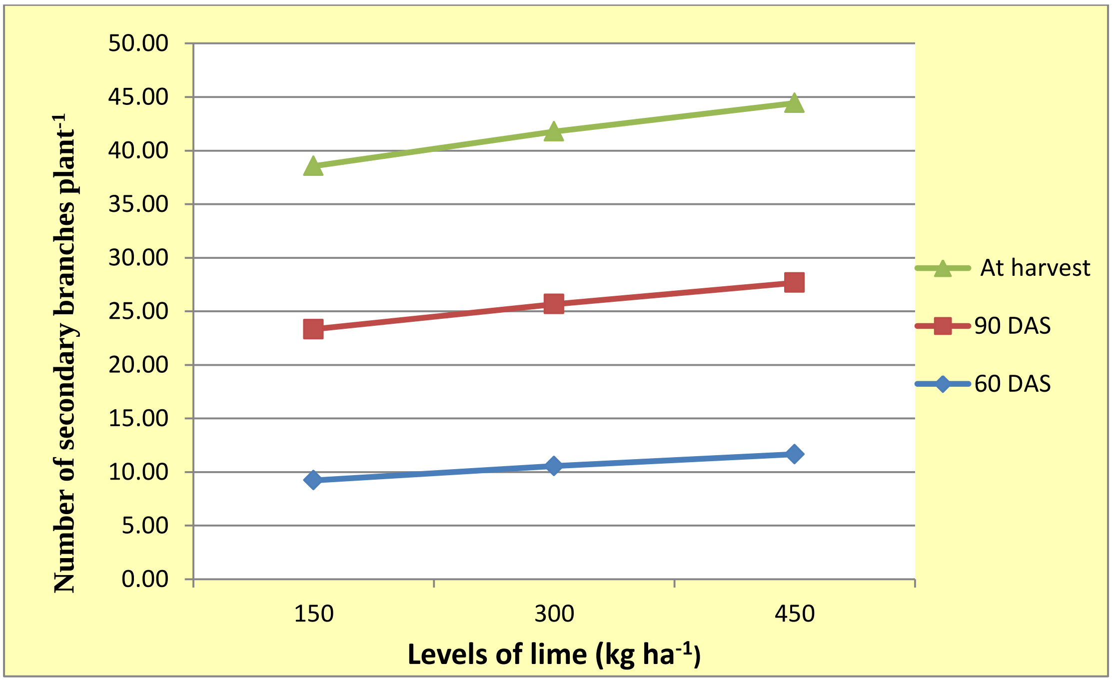
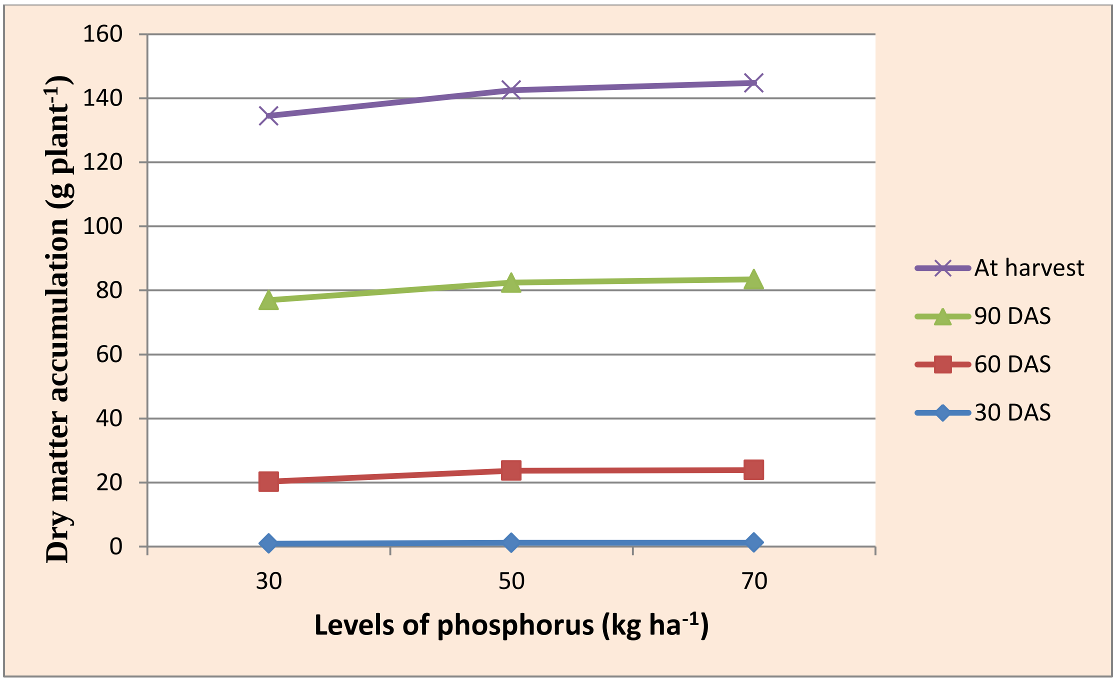




**Fig. 5.2: Effect of phosphorus and lime levels on number of secondary branches of Indian mustard under wood apple based agri-horti system.**



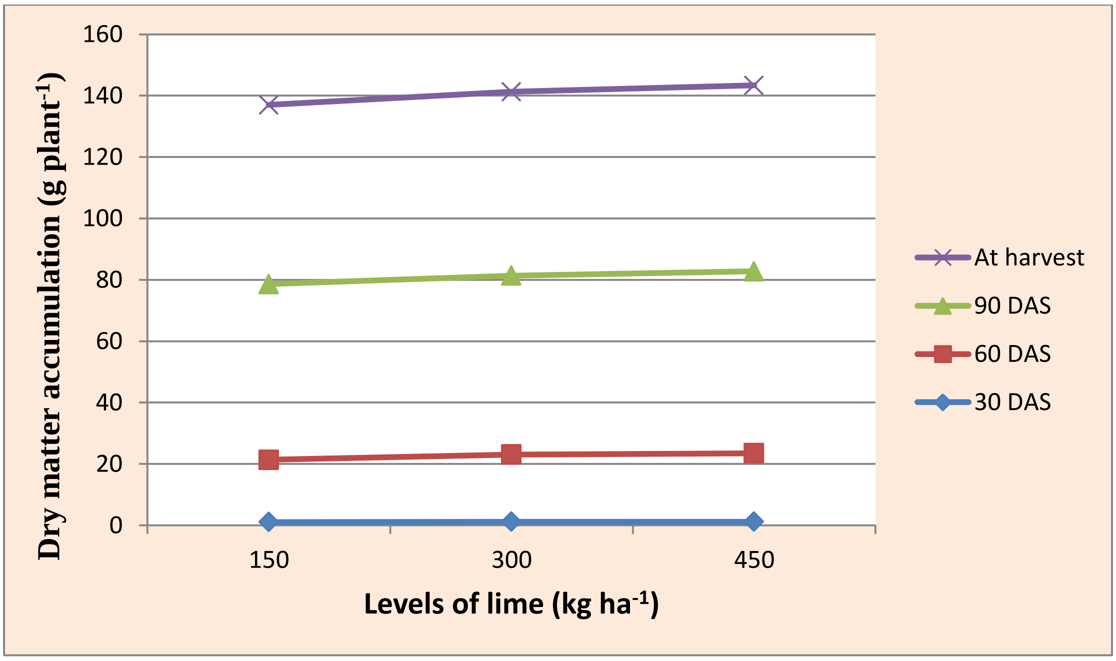




**Fig. 5.3: Effect of phosphorus and lime levels on dry matter accumulation of Indian mustard under wood apple based agri-horti system**

### 5.2.3 EFFECT OF PHOSPHORUS ON NUTRIENT CONTENT AND UPTAKE (kg ha$^{-1}$)

It is clearly visualized that nitrogen and phosphorus content in seed and stover increased with increasing application of phosphorus whereas, potassium was found to be non-significant. Higher nitrogen content in seed (3.4%) and stover (0.51%), phosphorus content in seed (0.77%) and stover (0.36%) were obtained by the application of 70 kg $P_2O_5$ ha$^{-1}$. Further, data also revealed that the 70 kg $P_2O_5$ was statistically at par with 50 kg $P_2O_5$ ha$^{-1}$.

Different levels of phosphorus have also affected nitrogen, phosphorus and potassium uptake by seed and stover of mustard. It was observed that NPK uptake by seed and stover increased with increasing levels of phosphorus. Higher nitrogen uptake by seed (47.3 kg ha$^{-1}$) and stover (28.7 kg ha$^{-1}$), phosphorus uptake by seed (11.0 kg ha$^{-1}$) and stover (20.5 kg ha$^{-1}$) and potassium uptake by seed (16 kg ha$^{-1}$) and stover (97.2 kg ha$^{-1}$) were obtained by the application of 70 kg $P_2O_5$ ha$^{-1}$. Phosphorus helps in root development and establishment which would have resulted in better uptake and utilization of nutrients from deeper soil layer.

Kumar and Yadav (2007) conducted an experiment to study the effect of phosphorus and sulphur levels on growth, yield and quality of Indian mustard and revealed that nutrient uptake increased with increasing rate of phosphorus and sulphur. The optimum dose of phosphorus and sulphur was estimated at 47.5 and 40 kg ha$^{-1}$, respectively. Similar findings were obtained by Singh *et al.* (2017).

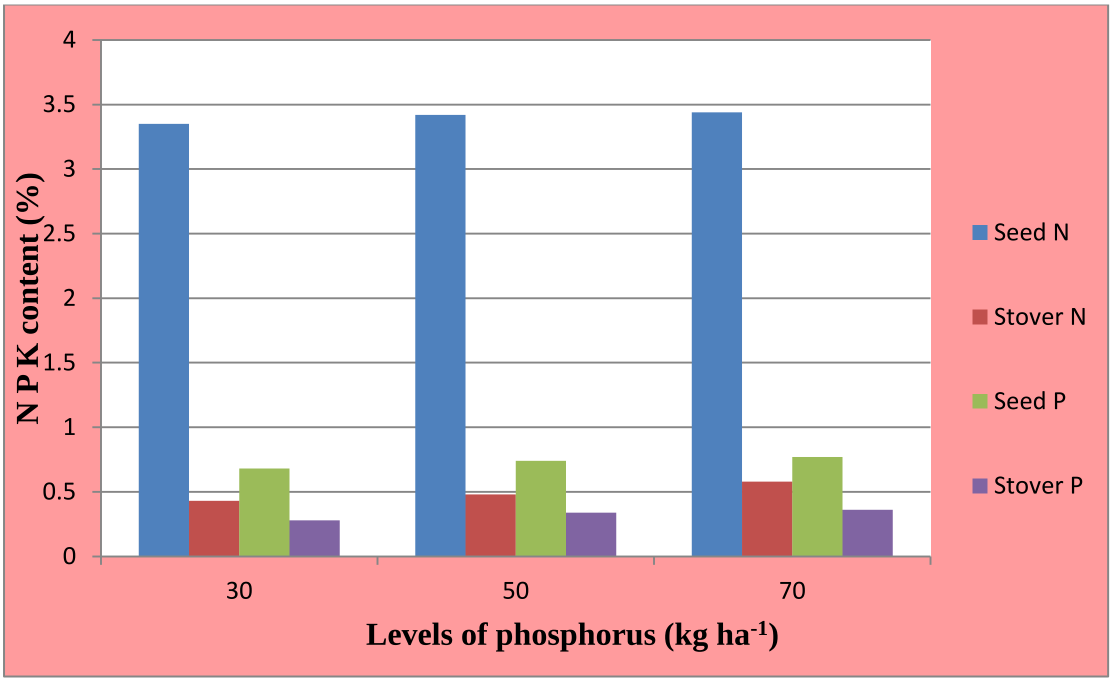
### 5.2.4 EFFECT OF PHOSPHORUS ON OIL CONTENT (%) AND OIL YIELD (kg ha$^{-1}$)

Different levels of phosphorus have also shown variation in the oil content and oil yield. It was noted out that higher oil content (39%) and oil yield (544 kg ha$^{-1}$) were observed at 70 kg $P_2O_5$ but was found to be statistically at par with 50 kg $P_2O_5$ ha$^{-1}$. This might be due to increased supply of phosphorus fertilizer as phosphorus enhances the oil content in mustard. Increment of phosphorus fertilizer resulted in better growth of branches, higher number of siliquae, higher growth of siliqua length and number of seeds siliqua$^{-1}$ that would have consequently increased the oil content and oil yield. Management of fertilizer is one of the most important agronomic factor that affects the yield of oilseed crops (Singh *et al.,* 2008). It is involved in a wide range of plant processes from permitting cell division to the development of a good root system (Singh *et al.*, 2015). Phosphate in presence of ATP is responsible for the synthesis of fatty acids in plants. These fatty acids contribute towards increasing the oil content. Similar results were also obtained by Lanjewar and Selukar (2005).

### 5.2.5 EFFECT OF PHOSPHORUS IN PROTEIN CONTENT (%) AND PROTEIN YIELD (kg $ha^{-1}$)

Different levels of phosphorus have shown variation in protein content and yield. Maximum protein content (21.2%) and protein yield (296 kg $ha^{-1}$) was obtained at 70 kg but was found to be statistically at par with 50 kg $P_2O_5$. This might be due to the fact that phosphorus fertilizer attributes towards increase in uptake and content of nitrogen, phosphorus and potassium which would have resulted in increasing the protein content and consequently protein yield.

Krishna e*t al.* (2005) studied the effect of phosphorus, sulphur and zinc fertilization on quality of mustard under semiarid conditions and found that oil, protein content and glucosinolate were higher at 30 kg $ZnSO_4$ and 60 kg each of phosphorus and sulphur $ha^{-1}$.



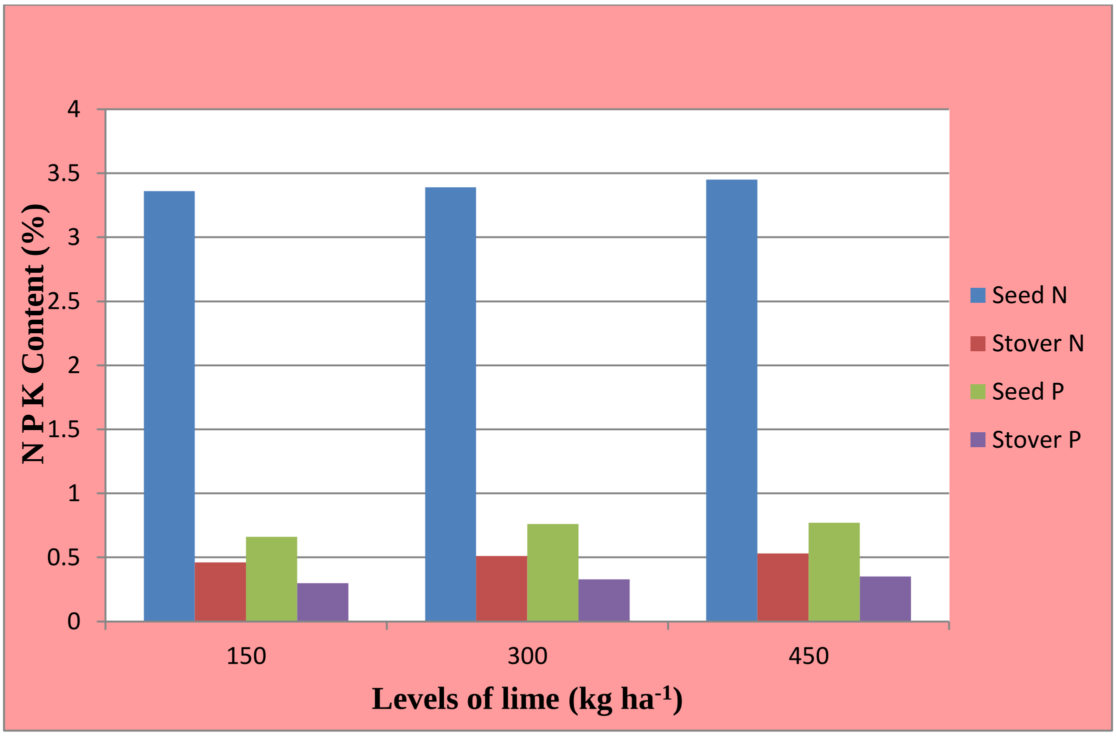
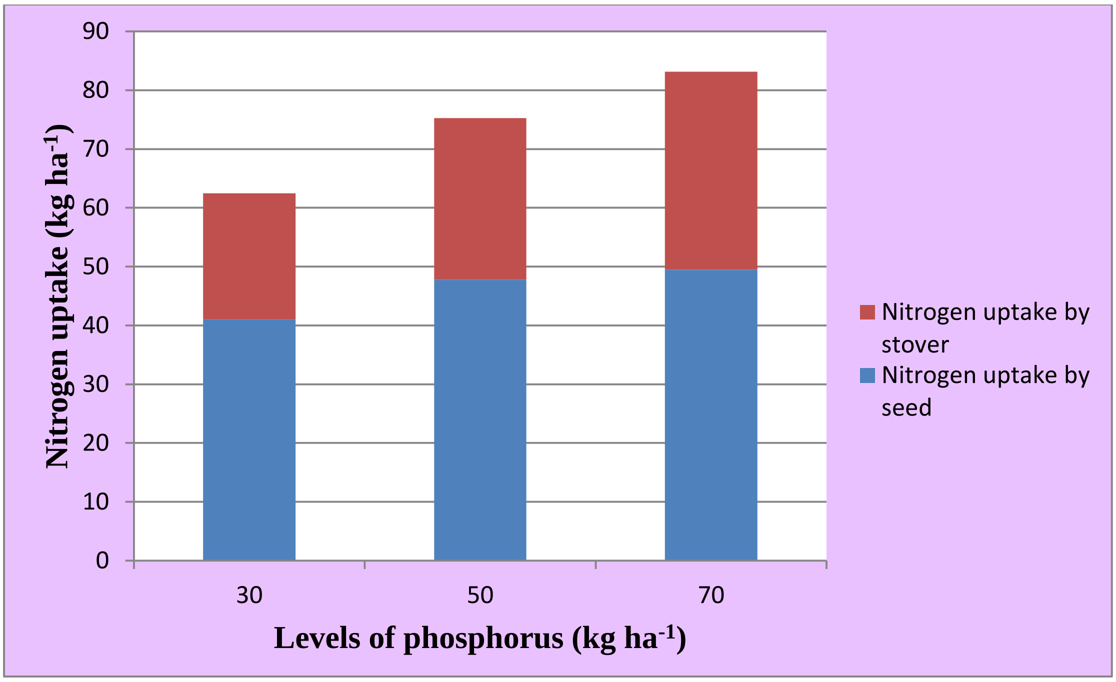




**Fig. 5.5: Effect of phosphorus and lime levels on N P K content (%) of Indian mustard under wood apple based agri-horti system.**



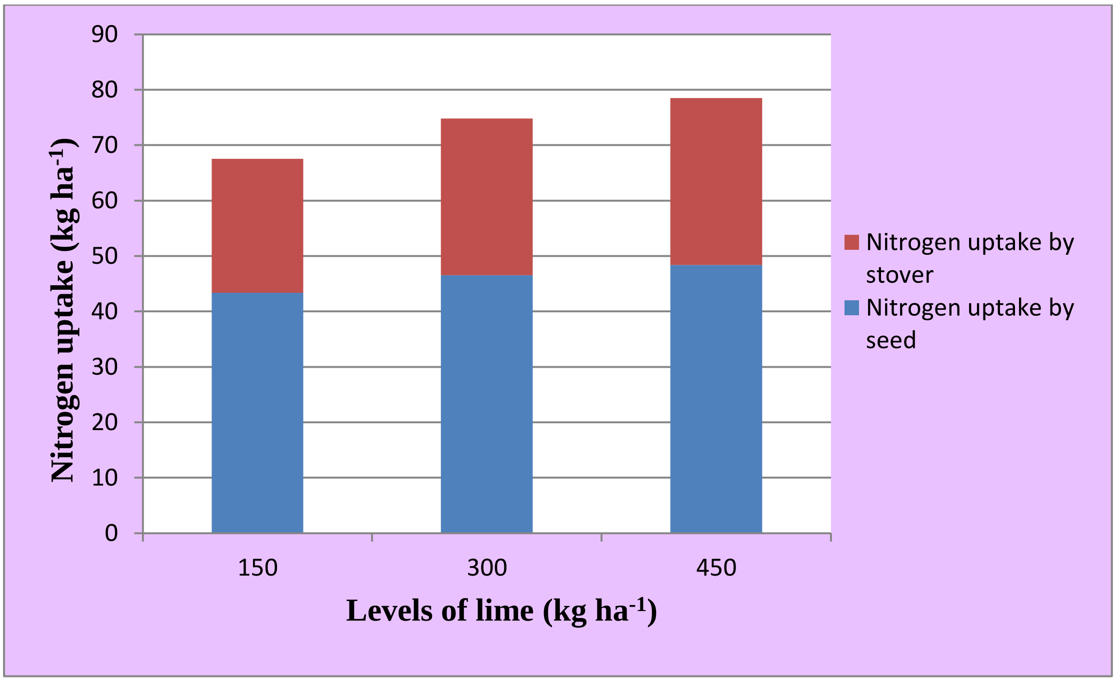




**Fig. 5.6: Effect of phosphorus and lime levels on nitrogen uptake of Indian mustard under wood apple based agri-horti system.**

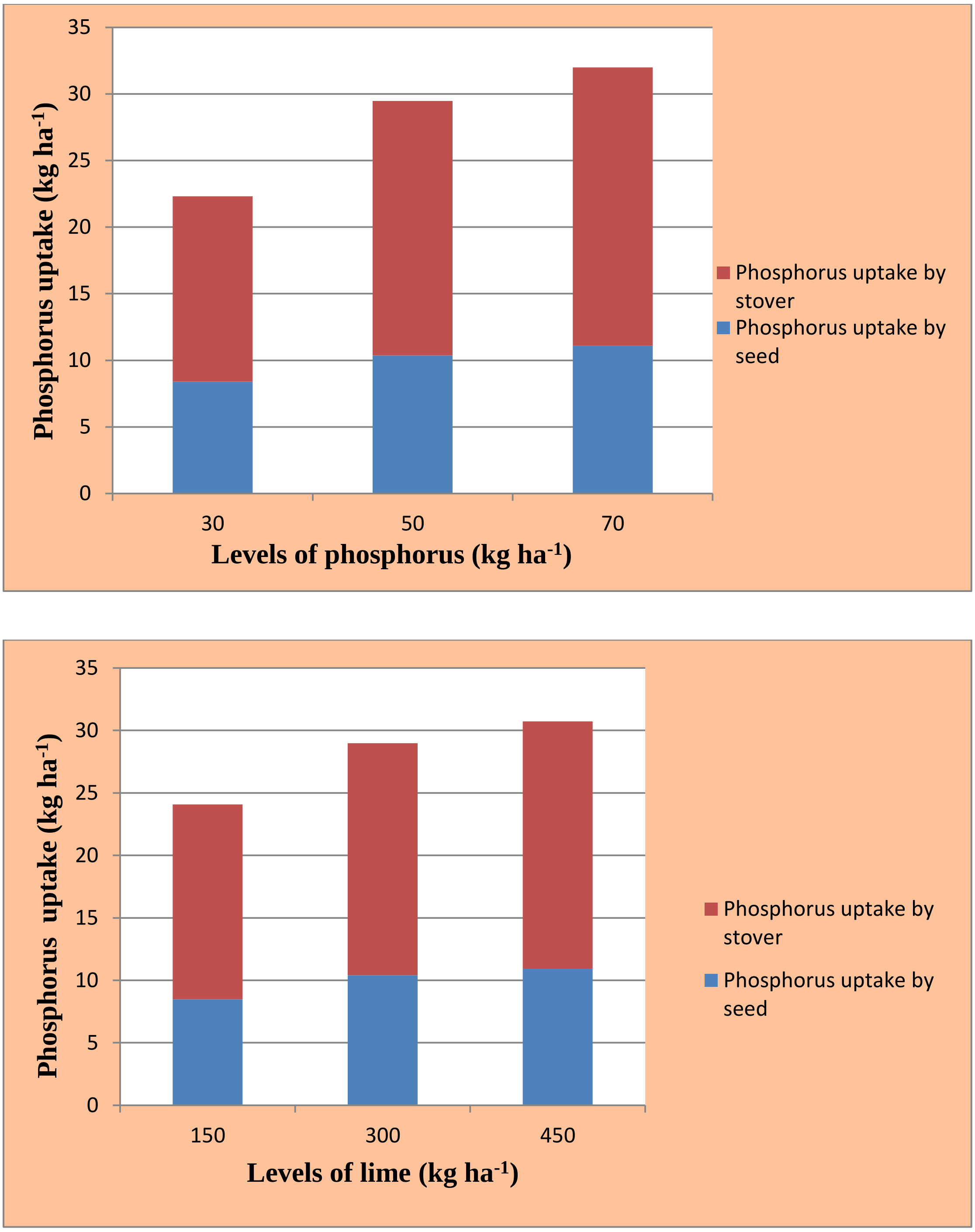
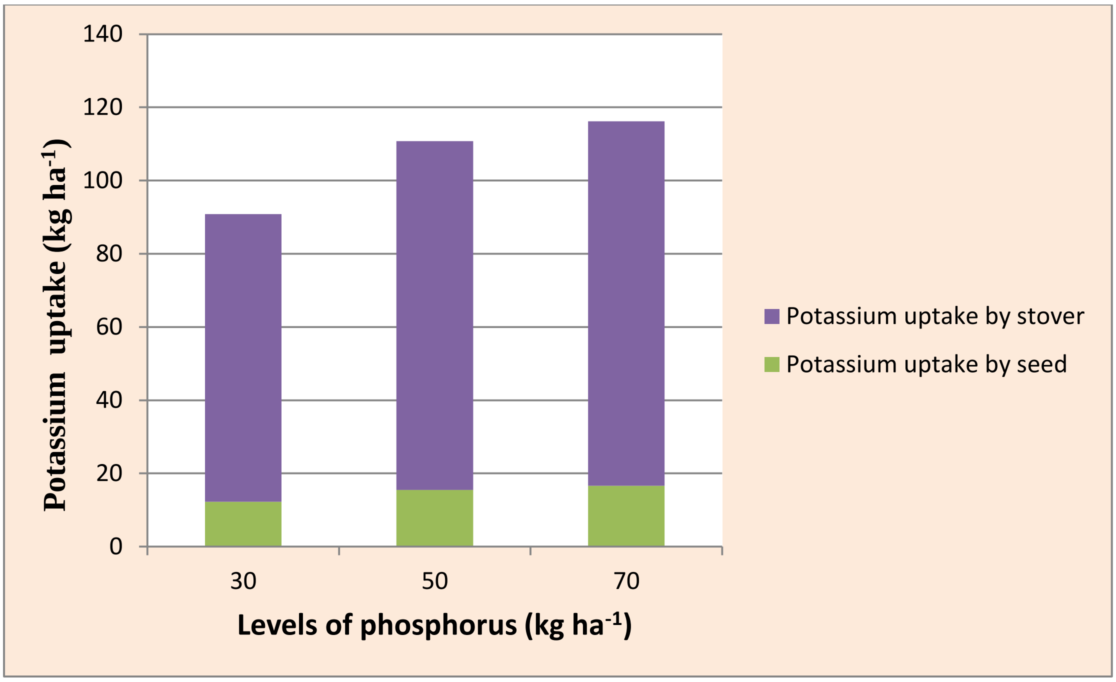



**Fig. 5.7: Effect of phosphorus and lime levels on phosphorus uptake of Indian mustard under wood apple based agri-horti system.**



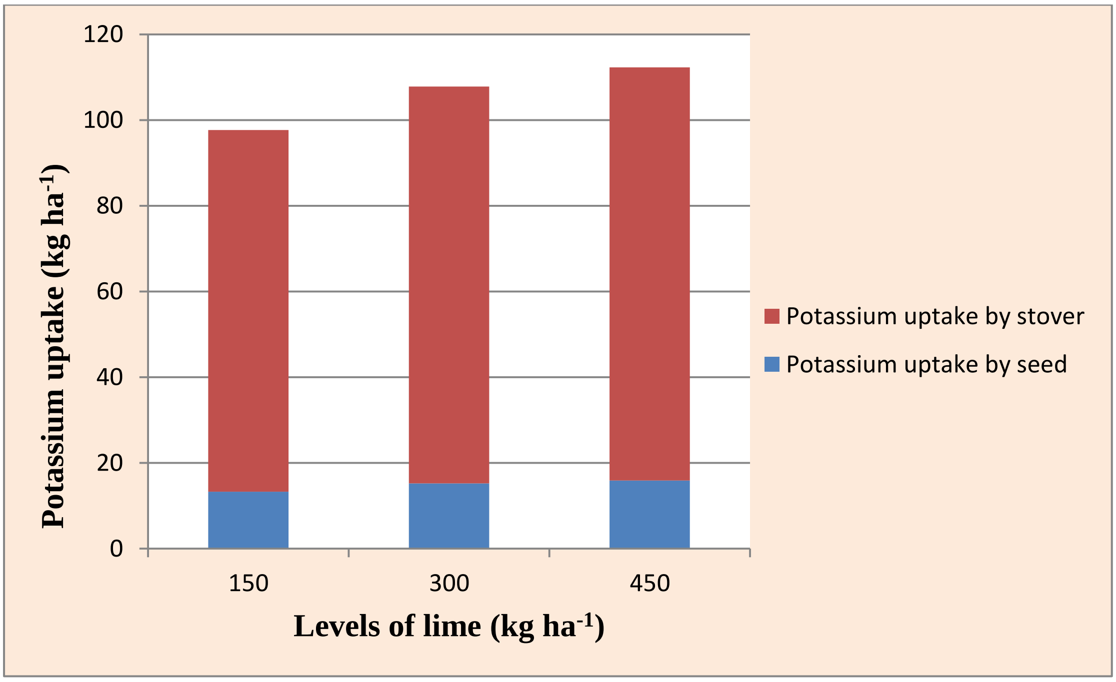
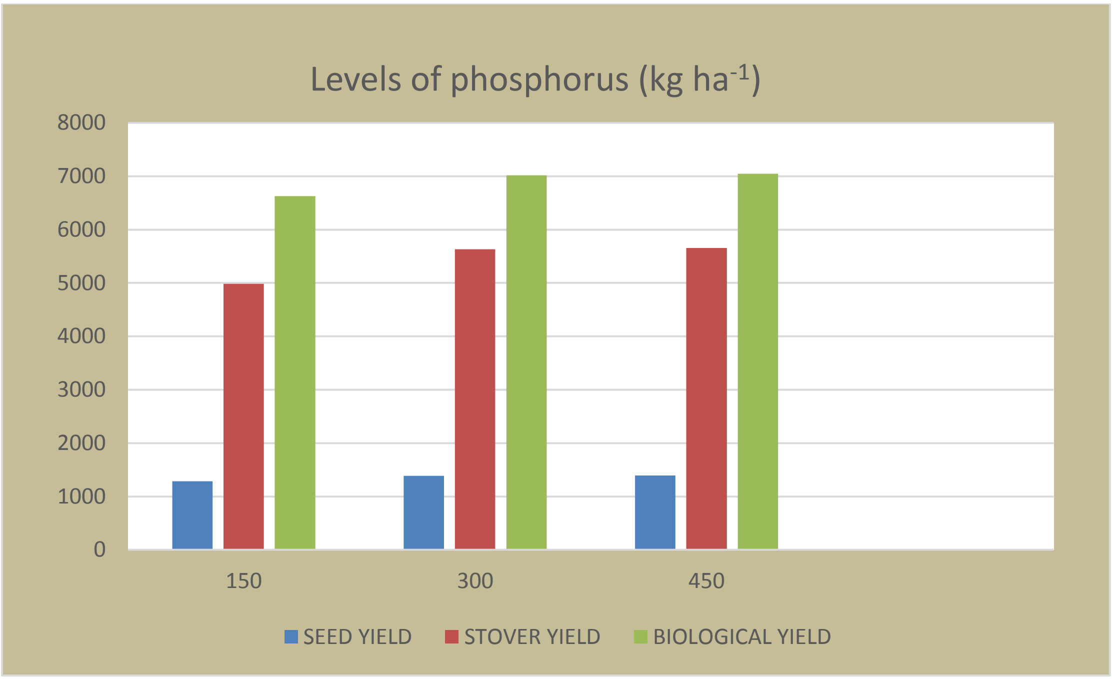




**Fig. 5.8: Effect of phosphorus and lime levels on potassium uptake (kg ha$^{-1}$) of mustard under wood apple based agri-horti system**



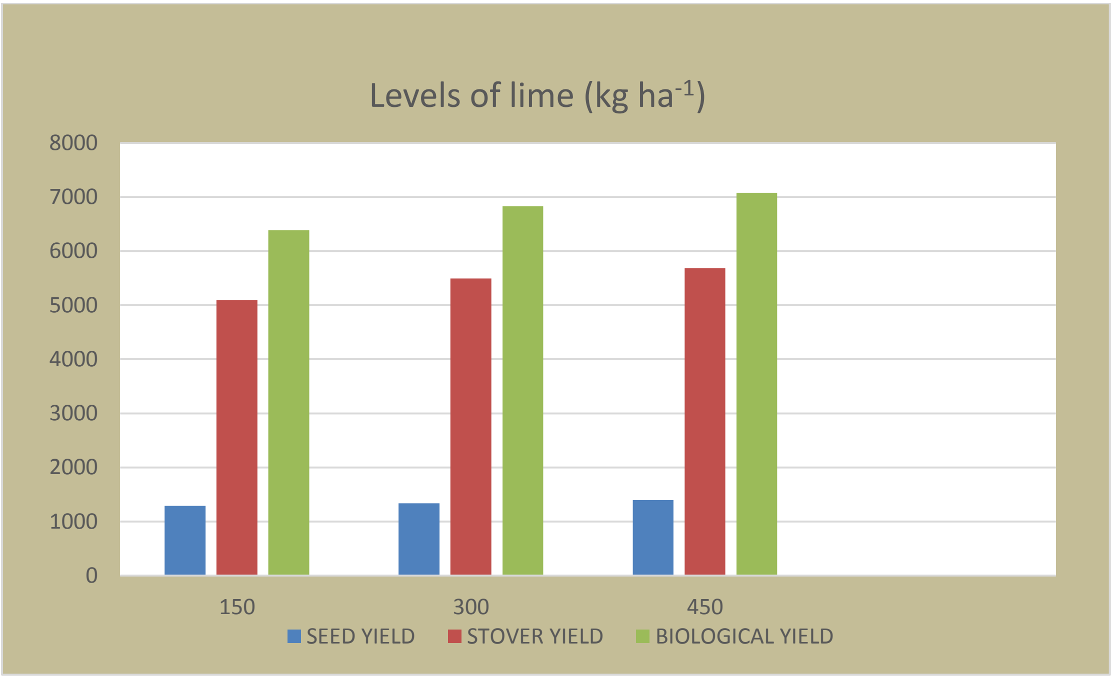
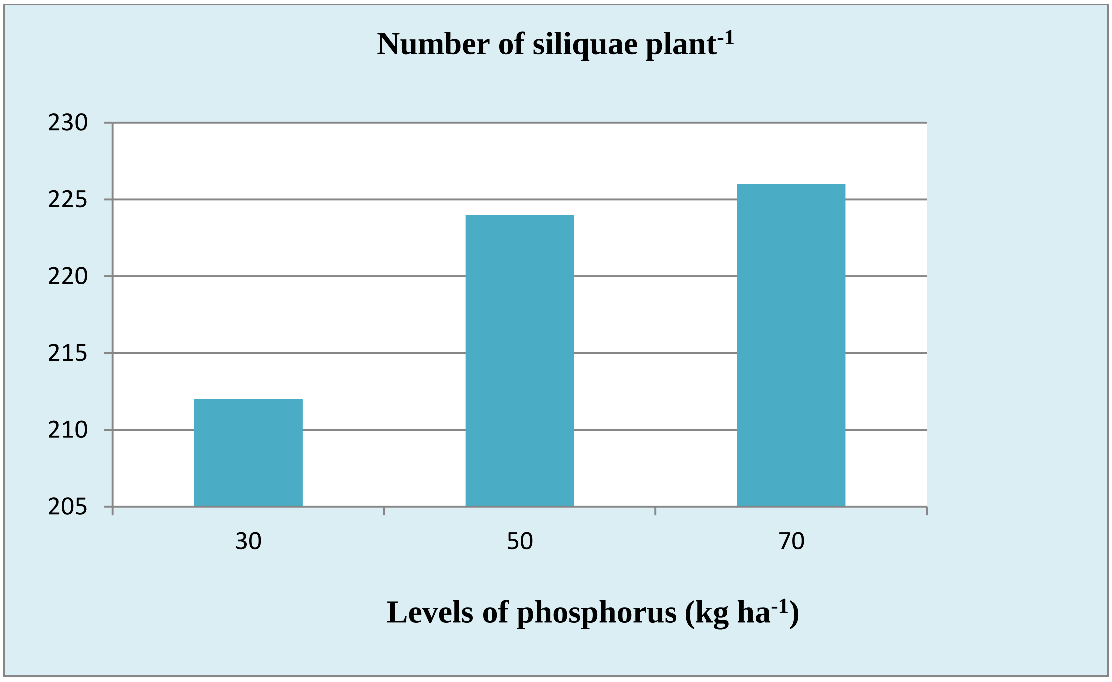




**Fig. 5.9: Effect of phosphorus and lime levels on yield and harvest index of Indian mustard under wood apple based agri-horti system.**



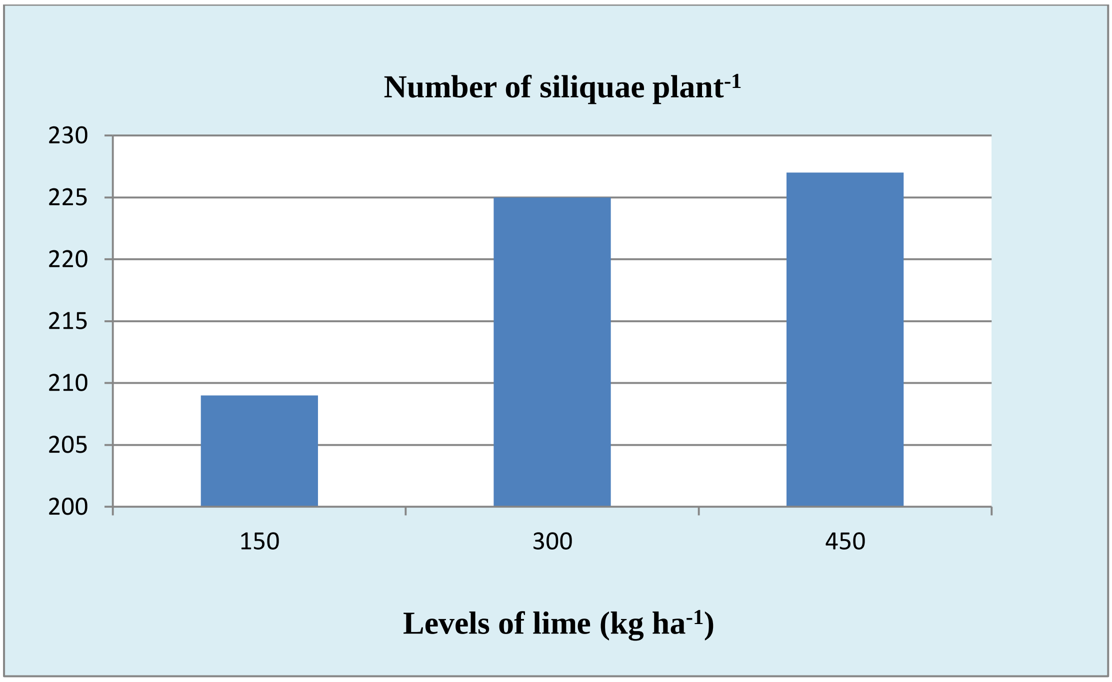
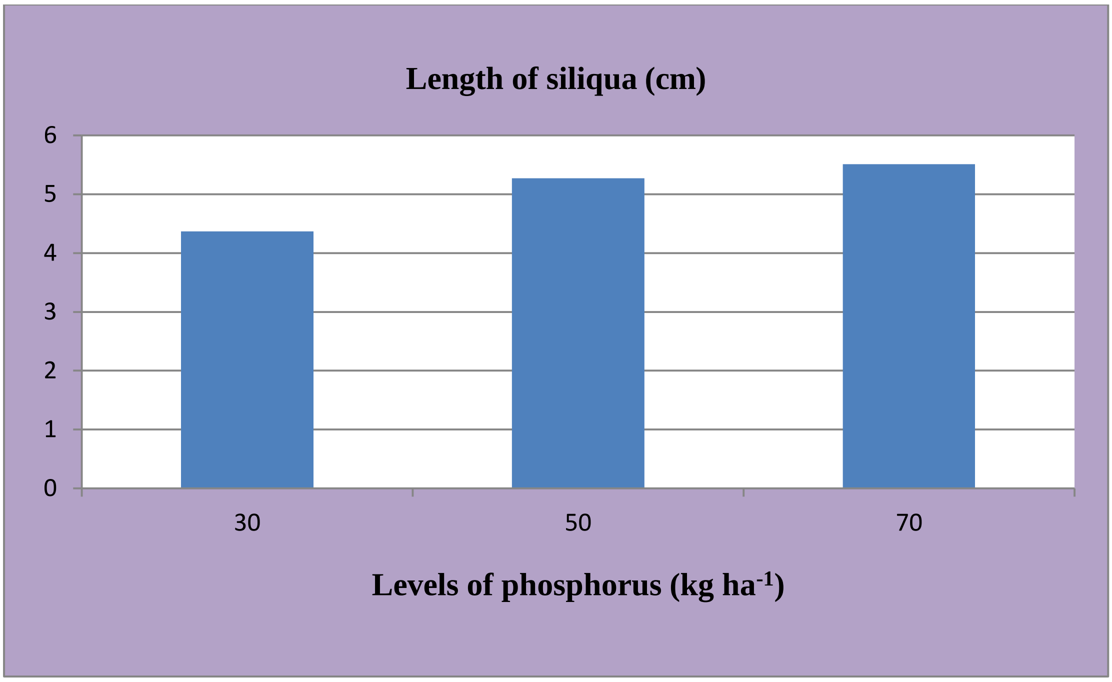




**Fig. 5.10: Effect of phosphorus and lime levels on number of siliquae plant$^{-1}$ of Indian mustard under wood apple based agri-horti system.**



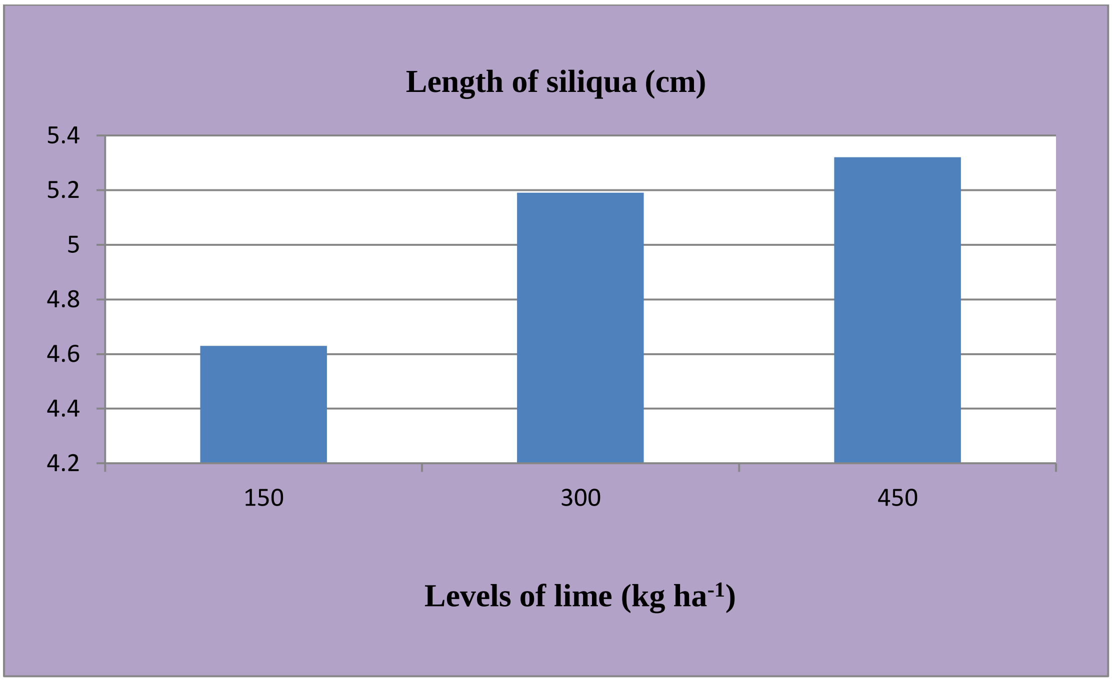
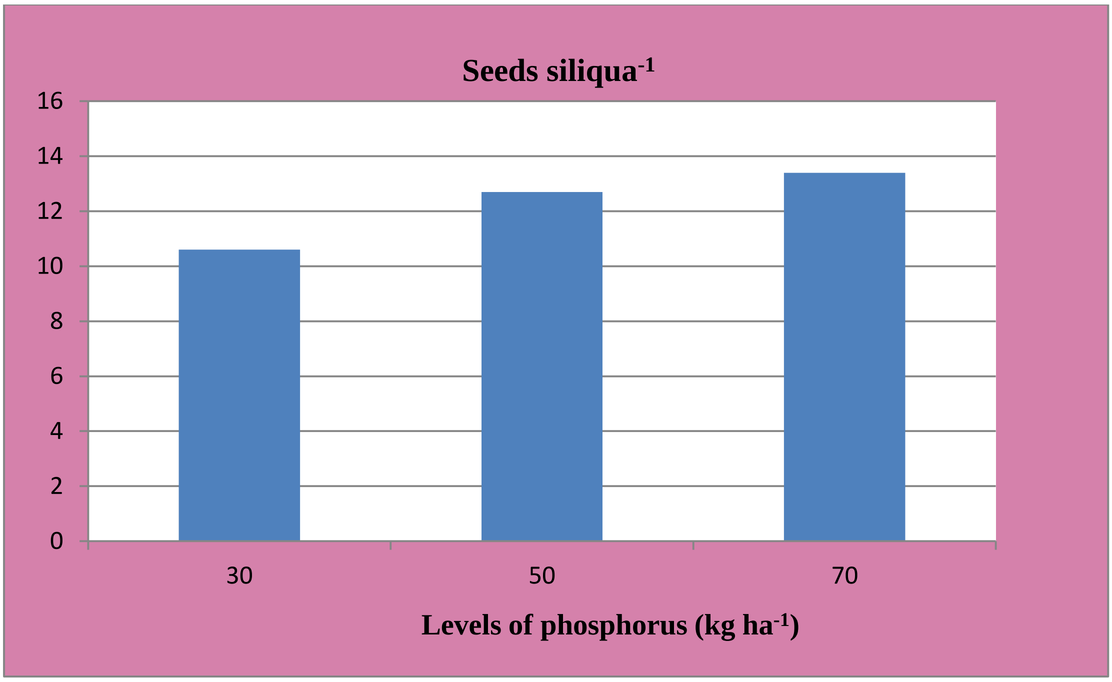




**Fig. 5.11: Effect of phosphorus and lime levels on length of siliqua of Indian mustard under wood apple based agri-horti system.**



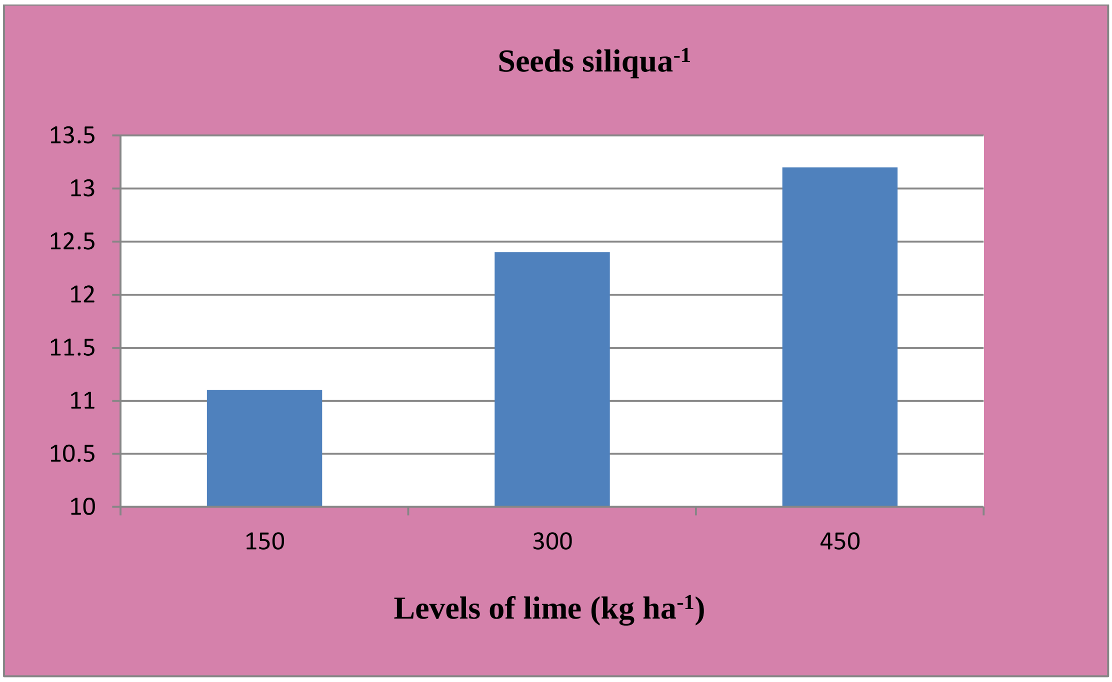




**Fig. 5.12: Effect of phosphorus and lime levels on seeds siliqua$^{-1}$ of Indian mustard under wood apple based agri-horti system.**

## 5.3 EFFECT OF LIME

### 5.3.1 EFFECT OF LIME ON YIELD ATTRIBUTES

The effect of varying levels of lime can be seen in growth and yield parameters of mustard. Mean of seed and stover yield presented in table 4.5 shows that it was significantly influenced by the application of different levels of lime. Increasing levels of lime (150, 300, 450 kg ha$^{-1}$) have significantly increased the seed and stover yield. The higher seed yield (1398 kg ha$^{-1}$) was obtained by the application of 450 kg lime ha$^{-1}$ over the control (1015 kg ha$^{-1}$) (no phosphorus, no lime) but it was statistically at par with 300 kg lime ha$^{-1}$, in the same way, the maximum stover yield (5680 kg ha$^{-1}$) was also obtained at 450 kg lime ha$^{-1}$ over the control (4107 kg ha$^{-1}$) but it was statistically at par with 300 kg lime ha$^{-1}$. The probable reason for increase in yield might be due to increase in seeds siliqua$^{-1}$, number of siliquae plant$^{-1}$, seed weight, siliqua length and other growth attributes. The significant increment in economic yields would be due to increment in growth and yield attributes of the crop. Increasing levels of lime ha$^{-1}$ would have influenced the growth because lime helps to reduce the acidic pH of soil which is a major cause for hindering the growth of crop in acid soils. Liming helps to reduce the toxicity of aluminium.

### 5.3.2 EFFECT OF LIME ON GROWTH PARAMETERS

Data recorded of the present experiment evidenced that growth parameters such as plant height, number of secondary branches, siliqua length (cm) and dry matter accumulation were affected by the levels of lime (150, 300, 450 kg lime ha$^{-1}$). It was observed that the plant height (166 cm) and secondary branches (16) at harvest, siliqua length (5.32 cm) and dry matter accumulation (60.6 g) at harvest was recorded as highest at 450 kg lime ha$^{-1}$. It was further, observed that results obtained at 300 kg was at par with 450 kg lime ha$^{-1}$. Increment in growth parameters with increasing lime levels might be due its contribution in enhancing the growth activity.

### 5.3.3 EFFECT OF LIME ON NUTRIENT CONTENT (%) AND UPTAKE (kg $ha^{-1}$)

It is clearly visualized that nitrogen and phosphorus contents in seed and stover increased with increasing application of lime. Higher nitrogen content in seed (3.39 %) and stover (0.51%) and phosphorus content in seed (0.77%) and stover (0.35%) were obtained by the application of 450 kg lime $ha^{-1}$ over rest of the treatment. Further, data also revealed that the 450 kg lime was statistically at par with 350 kg lime $ha^{-1}$ in respect of nitrogen and phosphorus contents in seed as well as in stover. Acidic soil reduces the uptake of nutrients by crops might be due to high concentration of aluminium ions in soil which caused toxic effect on growth of root. Liming cause pH dependent charge to increase, increases precipitation of exchangeable aluminium and stimulates root growth at depth depending upon rate and time after application (Dereje *et al.* 2019). Different levels of lime have also affected nitrogen, phosphorus and potassium uptake by seed and stover of mustard. It was observed that NPK uptake by seed and stover increased with increasing levels of lime. The higher nitrogen uptake by seed (47.5 kg $ha^{-1}$) and stover (28.8 kg $ha^{-1}$), phosphorus uptake by seed (10.7 kg $ha^{-1}$) and stover (20.0 kg $ha^{-1}$) and potassium uptake by seed (15.9 kg $ha^{-1}$) and stover (96.1 kg $ha^{-1}$) were obtained by the application of 450 kg lime $ha^{-1}$.

Toxicity of Al at low pH <5.0 to 5.5 limits the organic matter breakdown through microbial activity, excess of aluminium also hinderes division of cell at root tip and reduces lateral growth of root, reduces replication of DNA by increasing the complexity of double helix DNA thus interferes with uptake, translocation and transportation of essential elements like Na, K, P, Fe, Ca and Mo. The greatest benefit of lime application is reducing the toxicity of aluminium (Sarkar *et. al*,2013). An experiment was also conducted by them to study the effect of lime , NPK, FYM on organic carbon, nutrient status, pH of acid soil and found that nutrient uptake was maximum with application of FYM+ 50% NPK + Lime followed by 100% NPK+Lime, 100% NPK over Farmers' practice field in decreasing order.

Liming improves the conditions for growth of plants by neutralizing the pH, increasing availability of phosphorus and basic cation, which results in increasing uptake of nutrition (Effa, 2012)

### 5.3.4 EFFECT OF LIME ON OIL CONTENT (%) OIL YIELD (kg ha$^{-1}$)

It was noticed that higher oil content (38.8%) and oil yield (543 kg ha$^{-1}$) were recorded at 450 kg lime but was found to be non-significant with 300 kg lime ha$^{-1}$. Increasing oil content with increasing level of lime might be due to higher nutrient uptake, increment in seed yield, seed weight and number of seed siliqua$^{-1}$.

Similar result was found by Rao and Shakatawat (2000).

Liming is widely accepted amelioration practice for efficient utilization of applied and native soil nutrients and economic use of fertilizers applied (Sarkar *et al.,* 2013).

### 5.3.5 EFFECT OF LIME ON PROTEIN CONTENT (%) AND PROTEIN YIELD (kg ha$^{-1}$)

It was noticed that higher protein content (21.2%) and protein yield (297 kg ha$^{-1}$) was recorded at 450 kg lime but it was statistically at par with 300 kg lime ha$^{-1}$. Increase in protein content might be due to increase in nitrogen content and uptake by crop. Protein content and uptake is directly influenced by the nitrogen uptake of crop which is increased by the application of lime on acidic soil.

Similar results were found by Rao and Shaktawat (2000).

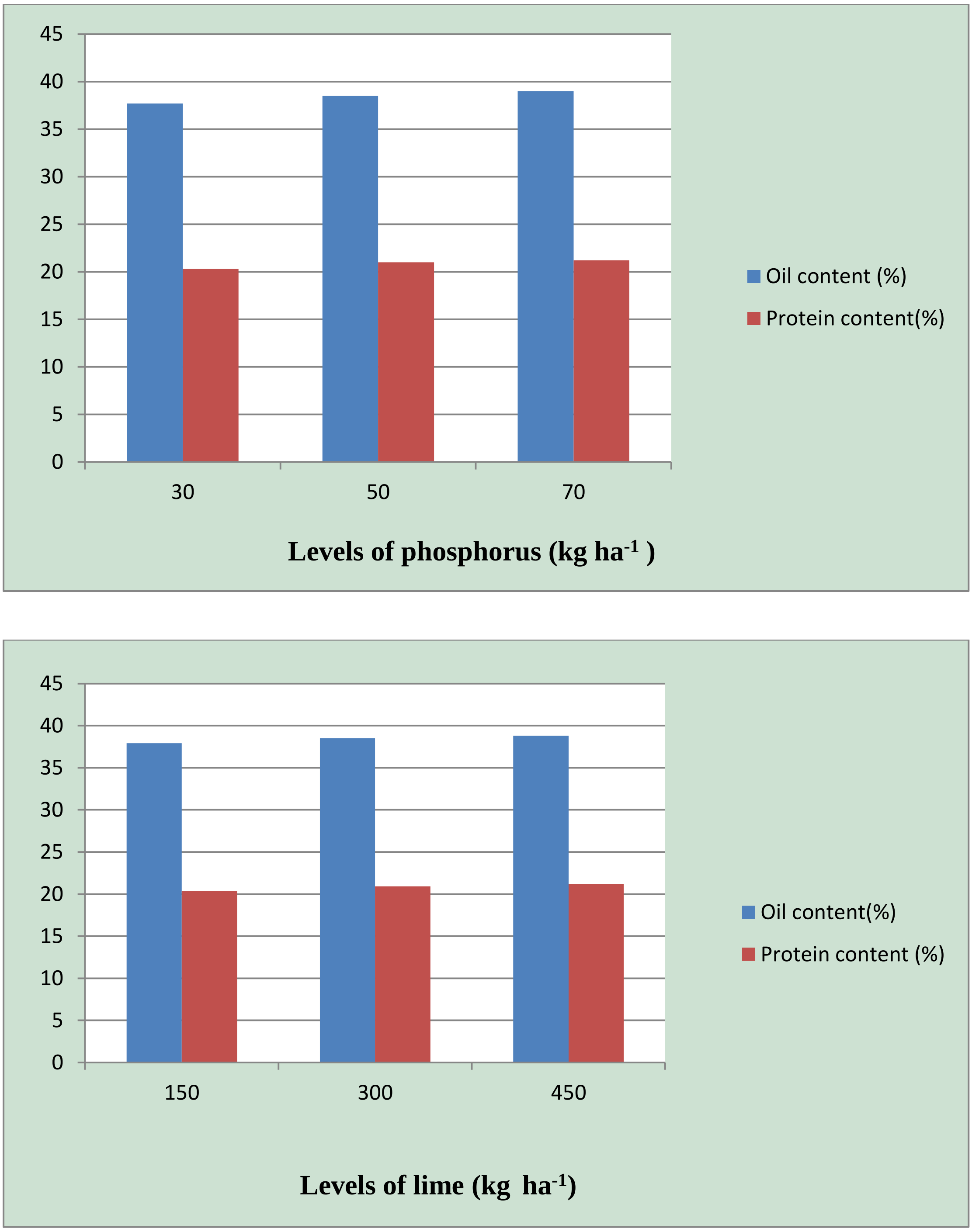
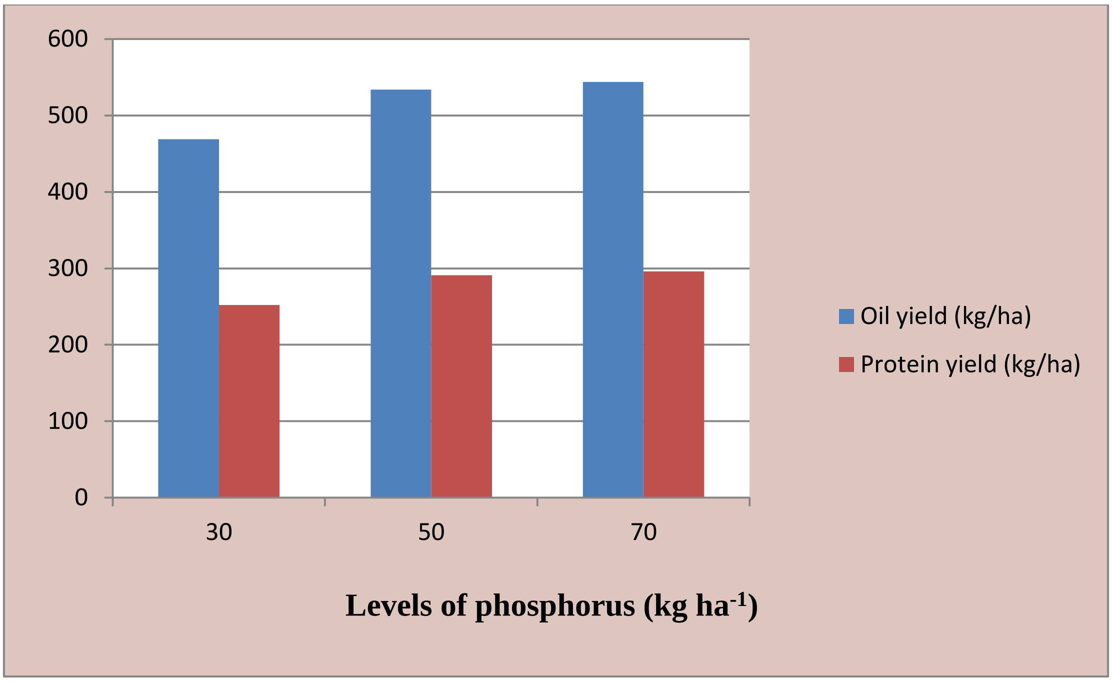



**Fig. 5.13: Effect of phosphorus and lime levels on oil and protein content of Indian mustard under wood apple based agri-horti system.**



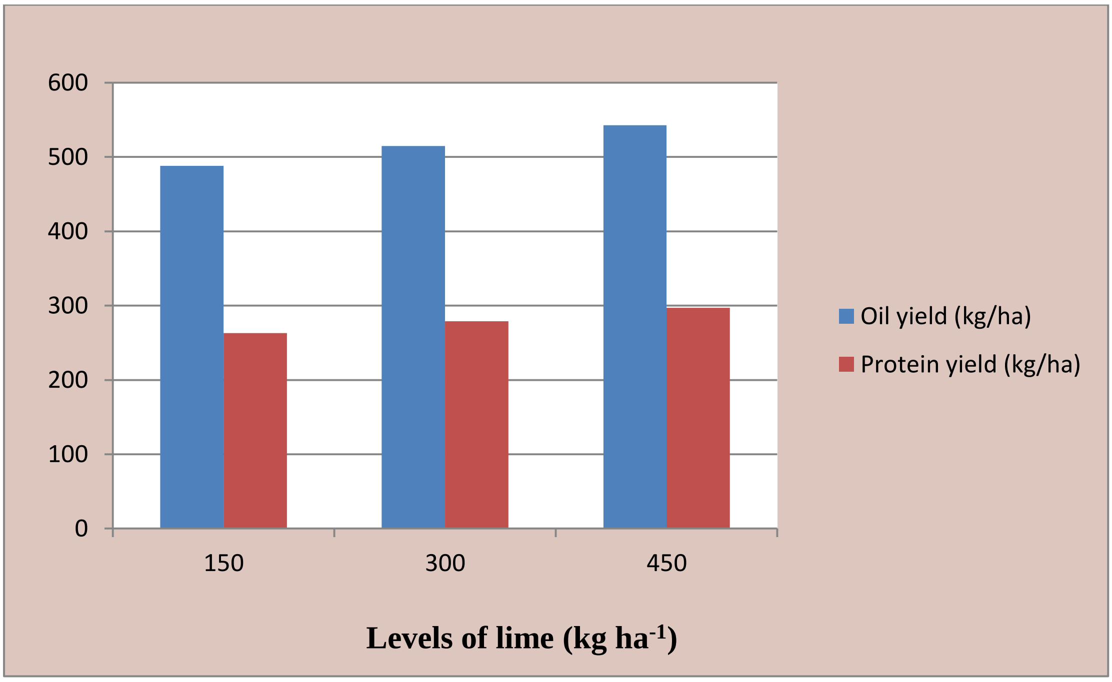




**Fig. 5.14: Effect of phosphorus and lime levels on oil and protein yield of Indian mustard under wood apple based agri-horti system.**


Fig. 5.15: Cultivation of Indian mustard on wood apple based agri-horti system.

## 5.4 RELATIVE ECONOMICS

The effect of phosphorus and lime would have helped in reducing the acidity, increasing the nutrient availability of soil which would have helped in higher yield and growth of crop. Higher yield and growth contributed towards profitable gross income and net return.

Among different treatment combinations, 50 kg $P_2O_5$ along with 450 kg lime $ha^{-1}$ gave the maximum gross income (Rs 139646 $ha^{-1}$) and maximum net return (Rs 99914 $ha^{-1}$) followed by 50 kg $P_2O_5$ with 300 kg lime $ha^{-1}$ (Rs 97668 $ha^{-1}$).

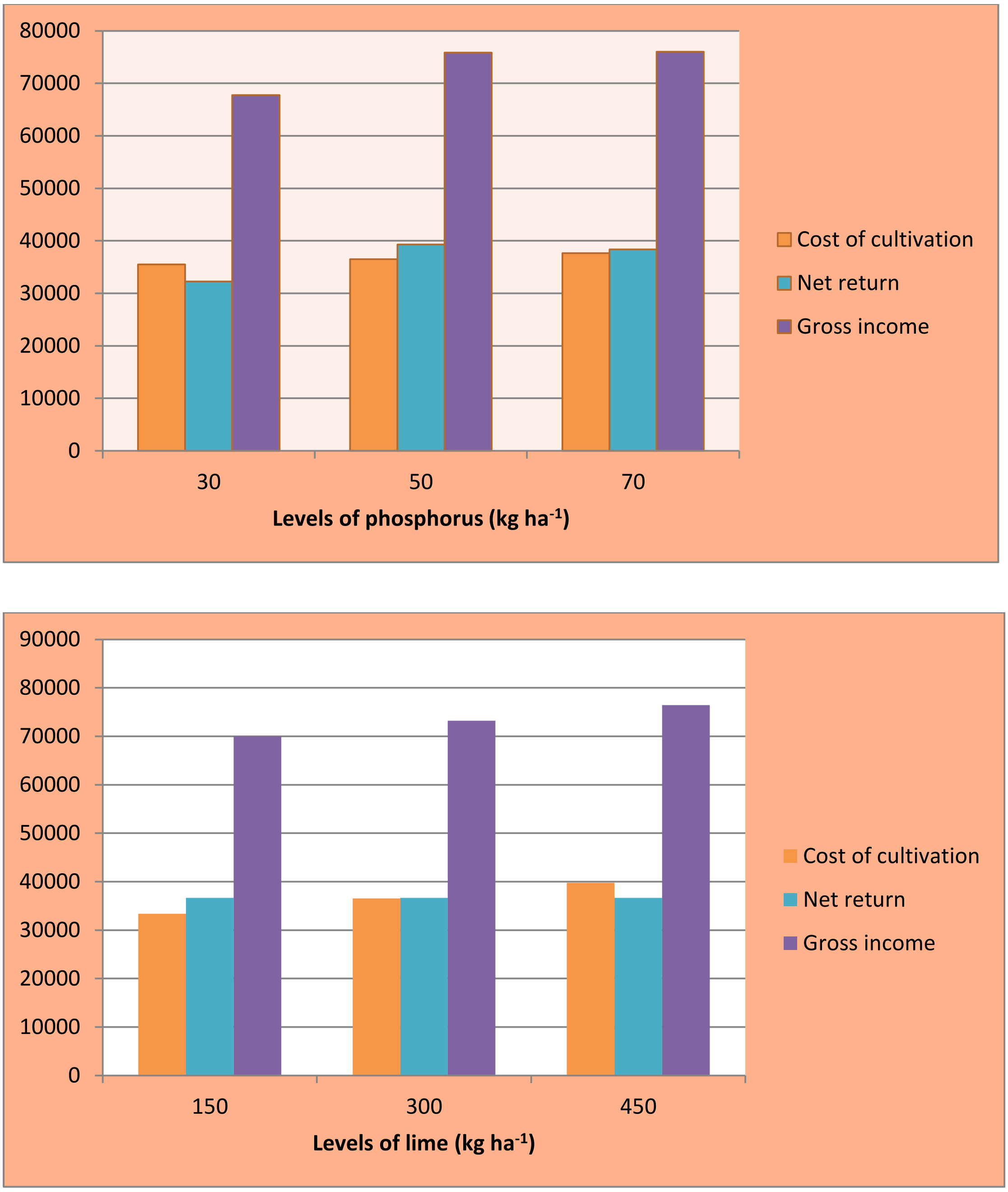



**Fig. 5.16: Effect of phosphorus and lime levels on economics of Indian mustard under wood apple based agri-horti system.**

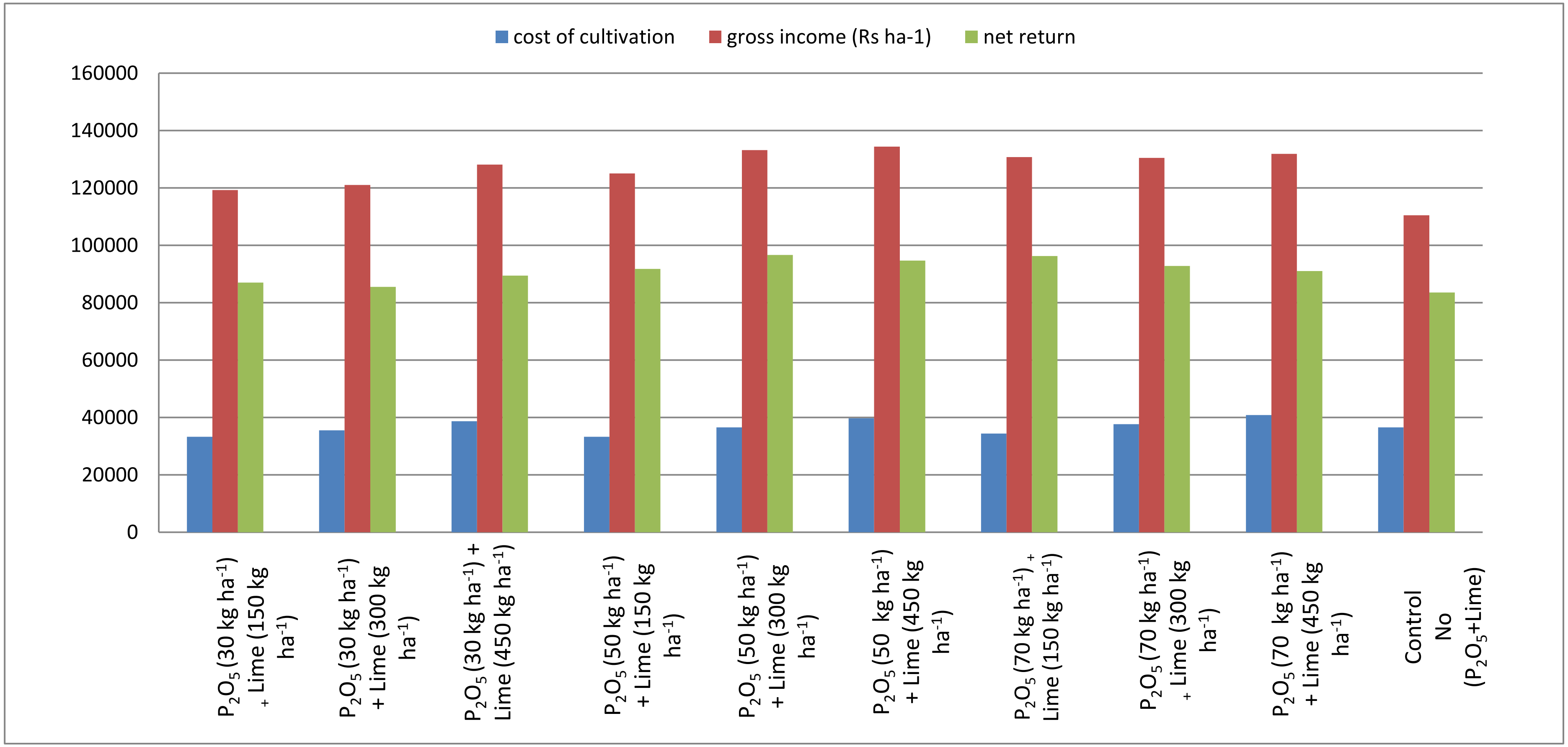



**Fig. 5.17: Effect of different treatment combination of phosphorus and lime levels on economics of Indian mustard under wood apple based agri-horti system.**

*Chapter VI*

# SUMMARY AND CONCLUSION

This chapter deals with summarization and conclusion of proceeding chapters of the experiment entitled as **"Effect of phosphorus and lime levels on mustard (*Brassica juncea* L.) under wood apple (*Aegle marmelos* L.) based agri-horti system"** which was piloted in winter (*Rabi*) season of 2019-2020 at Agricultural Research Farm of Rajiv Gandhi South Campus, Barkachha, Banaras Hindu University, Mirzapur. The field experiment was conducted in factorial randomized block design with three levels each of phosphorus (30, 50, 70 kg ha$^{-1}$) and lime (150, 300, 450 kg ha$^{-1}$) in three replications.

The soil of experimental field was characterized as sandy loam, low in available nitrogen (179.6 kg ha$^{-1}$) and phosphorus (13.1 kg ha$^{-1}$), medium in available potassium (183.25 kg ha$^{-1}$) and acidic pH as 5.9. Mustard seeds with seed rate of 5 kg ha$^{-1}$ were sown at a spacing of 45 cm row-to-row and 10 cm plant-to-plant. The recommended dose of nitrogen and potassium (90 and 30 kg ha$^{-1}$) was applied to crop. Nitrogen and potassium was applied by the application of urea (46% N) and muriate of potash (60% $K_2O$), respectively. Half dose of nitrogen and full dose of $K_2O$ was applied as basal and remaining dose of nitrogen was applied to crop at knee height stage.

Growth observations which includes plant height, number of secondary branches plant$^{-1}$, dry matter accumulation, siliqua length and yield attributes which includes seed weight (g), seeds siliqua$^{-1}$, seed yield (kg ha$^{-1}$), stover yield (kg ha$^{-1}$) as well as quality parameters *viz*., NPK uptake and content by seed and stover, oil content and oil yield, protein content and protein yield were also noted. Economics of treatment *viz*., net return and benefit-cost ratio was also worked out.

Observed data was clearly analyzed and is summarized as under,

## EFFECT OF PHOSPHRUS LEVELS

- Increasing levels of phosphorus increased the growth parameters such as plant height, number of secondary branches, dry matter accumulation (DMA), siliqua length up to 70 kg $P_2O_5$ followed by 50 kg $P_2O_5$ $ha^{-1}$.
- The yield attributing characters of crop have shown increment with increasing levels of phosphorus and it was observed that more seeds $siliqua^{-1}$, number of siliquae $plant^{-1}$, seed weight (g), seed yield (kg $ha^{-1}$) and stover yield (kg $ha^{-1}$) was obtained at 70 kg $P_2O_5$ followed by 50 kg $P_2O_5$ $ha^{-1}$.
- Application of phosphorus at 70 kg $P_2O_5$ have shown maximum content and uptake of NPK whereas minimum was obtained at 30 kg $P_2O_5$ $ha^{-1}$.
- Application of phosphorus at 70 kg have also exhibited higher oil content, oil yield, protein content and protein uptake whereas minimum was obtained at 30 kg $P_2O_5$ $ha^{-1}$.

## EFFECT OF LIME LEVELS

- The increasing levels of lime increased the growth parameters such as plant height, number of secondary branches, dry matter accumulation (DMA), siliqua length up to 450 kg lime $ha^{-1}$. On the basis of the given data all growth parameter were recorded as highest with 450 kg lime $ha^{-1}$ while the lowest with 150 kg lime $ha^{-1}$
- The yield attributing characters of crop have shown increment with increasing levels of lime and it was observed that higher seeds $siliqua^{-1}$, number of siliquae $plant^{-1}$, seed weight (g), seed yield (kg $ha^{-1}$) and stover yield (kg $ha^{-1}$) was obtained with 450 kg lime followed by 300 kg lime $ha^{-1}$.
- Application of 450 kg lime $ha^{-1}$ have shown maximum NPK content and uptake whereas minimum was obtained at 150 kg lime $ha^{-1}$.

## RELATIVE ECONOMICS

The treatment combination of 70 kg $P_2O_5$ with 450 kg lime $ha^{-1}$ have recorded the maximum cost of cultivation whereas, maximum net return was recorded with the application of 50 kg $P_2O_5$ + 450 kg lime $ha^{-1}$ (Rs 99914 $ha^{-1}$).

## CONCLUSION

The application of phosphorus at 50 kg along with 450 kg lime $ha^{-1}$ to mustard grown under wood apple based agri-horti system proved profitable for boosting seed yield (1456 kg $ha^{-1}$) and gave the maximum net return, thus it could be recommended for most remunerative production of mustard under *Vindhyan* region of Mirzapur.

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# APPENDICES

**Appendix I: Growth parameter of wood apple tree at the time of sowing.**

| Fruit tree species | Height (meter) | Canopy diameter (meter) | Stem girth (cm) | Shading area | |
|---|---|---|---|---|---|
| | | | | Length (meter) | Width (meter) |
| Wood apple | 7.2 | 3.5 | 56.5 | 5.6 | 3.3 |

**Appendix II : Growth parameter of wood apple tree at 60 DAS.**

| Fruit tree species | Height (meter) | Canopy diameter (meter) | Stem girth (cm) | Shading area | |
|---|---|---|---|---|---|
| | | | | Length (meter) | Width (meter) |
| Wood apple | 7.4 | 3.8 | 57.0 | 5.8 | 3.6 |

**Appendix III: Growth parameter of wood apple tree at 90 DAS.**

| Fruit tree species | Height (meter) | Canopy diameter (meter) | Stem girth (cm) | Shading area | |
|---|---|---|---|---|---|
| | | | | Length (meter) | Width (meter) |
| Wood apple | 7.5 | 4.4 | 57.5 | 6.0 | 3.6 |

**Appendix IV : Growth parameter of wood apple tree at the time of harvest.**

| Fruit tree species | Height (meter) | Canopy diameter (meter) | Stem girth (cm) | Shading area | |
|---|---|---|---|---|---|
| | | | | Width (meter) | Length (meter) |
| Wood apple | 7.8 | 4.7 | 57.8 | 6.5 | 3.8 |

**Appendix V : Yield attributes , yield and economic return from fruit of wood apple**

| Fruit trees | Average number of fruits tree (ha$^{-1}$) | Average number of fruits tree$^{-1}$ | Average weight of fruit (g) | Fruit yield (kg ha$^{-1}$) | Rate (fruit kg $^{-1}$) | Gross income from fruit tree (Rs ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Wood apple | 6120 | 30 | 500 | 3060 | 18 | 55080 |

## Appendix VI : Common cost of cultivation (₹ $ha^{-1}$)

| S.No. | Operations | Input | Rate (₹ $unit^{-1}$) | Cost (₹ $ha^{-1}$) |
|---|---|---|---|---|
| 1 | Conventional tillage | | | |
| | (i) One deep ploughing by tractor for 3 hours | 35 HP for 2hrs | 700$hrs^{-1}$ | 1400 |
| | (ii) One harrowing and planking | 35 HP for 3hrs | 700$hrs^{-1}$ | 2100 |
| 2 | Layout | 10 Man-day | 300 $day^{-1}$ | 3000 |
| 3 | Seed sowing | 10 Man-day | 300 $day^{-1}$ | 3000 |
| 4 | Irrigation (2) | Water for two irrigation | 500/irrigation $ha^{-1}$ | 1000 |
| 5 | Fertilizer | | | |
| | MOP | 50 kg $ha^{-1}$ | 25 | 1250 |
| | Bentonite Sulphur | 30 kg $ha^{-1}$ | 90 | 2700 |
| 6 | Harvesting and Threshing | 20 man days | 300 man $day^{-1}$ | 6000 |
| 7 | Seed cost | 5 kg $ha^{-1}$ | 40 $kg^{-1}$ | 200 |
| 8 | Harvesting of fruit | 15 man days | 300 man $day^{-1}$ | 4500 |
| 9 | Land revenue | For 6 months | 350 $annum^{-1}$ | 175 |
| | | | Total | 25325 |

## Appendix VII: Variable cost

| Treatment | Dose of lime (kg ha$^{-1}$) | Cost of lime (₹) | Dose of DAP (kg ha$^{-1}$) | Cost of DAP (₹) | Dose of urea (kg ha$^{-1}$) | Cost of urea (₹) | Total cost (₹) | Interest on working capital @ 14% annum | Total cost of the Treatment (₹ ha$^{-1}$) | Total cost of cultivation =Common cost +Treatment cost ₹ha$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $P_1L_1$ | 150 | 3000 | 65 | 1755 | 191 | 1146 | 5901 | 826 | 6727 | 32052 |
| $P_1L_2$ | 300 | 6000 | 65 | 1755 | 191 | 1146 | 8901 | 1246 | 10147 | 35472 |
| $P_1L_3$ | 450 | 9000 | 65 | 1755 | 191 | 1146 | 11901 | 1666 | 13567 | 38892 |
| $P_2 L_1$ | 150 | 3000 | 109 | 2953 | 152 | 912 | 6865 | 961 | 7826 | 33151 |
| $P_2 L_2$ | 300 | 6000 | 109 | 2953 | 152 | 912 | 9865 | 1381 | 11246 | 36571 |
| $P_2 L_3$ | 450 | 9000 | 109 | 2953 | 152 | 912 | 12865 | 1801 | 14666 | 39991 |
| $P_3 L_1$ | 150 | 3000 | 152 | 4104 | 137 | 822 | 7926 | 1109 | 9035 | 34360 |
| $P_3 L_2$ | 300 | 6000 | 152 | 4104 | 137 | 822 | 10926 | 1530 | 12456 | 37781 |
| $P_3 L_3$ | 450 | 9000 | 152 | 4104 | 137 | 822 | 13926 | 1861 | 15787 | 41112 |
| CONTROL | 0 | 0 | 0 | 0 | 196 | 1176 | 1176 | 165 | 1341 | 26666 |
| OPEN | 300 | 6000 | 109 | 2953 | 152 | 912 | 9865 | 1381 | 11246 | 36571 |

Cost of lime= ₹ 20 kg$^{-1}$, Cost of DAP= ₹ 27 kg$^{-1}$
Cost of urea = ₹ 6 kg$^{-1}$