Effect of nutrient management through FYM and bio-inoculants in mungbean [*Vigna radiata* (L.) Wilczek] under custard apple (*Annona squamosa* L.) based Agri-horti system

काशी हिन्दू विश्वविद्यालय

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in

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Submitted by

Monika Jaiswal

Supervisor

Prof. Ramesh Kumar Singh

Co-Supervisor

Prof. Sant Prasad

DEPARTMENT OF AGRONOMY
INSTITUTE OF AGRICULTURAL SCIENCES
BANARAS HINDU UNIVERSITY
VARANASI (UP) – 221 005
INDIA

ID. No. 17430AGF012 2019 Enrolment No. 401476

Dr. Ramesh Kumar Singh
Professor
Phone: +91-9450533438 (M)
Email: rks1660bhu@gmail.com

Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University
Varanasi - 221005, U.P. (INDIA)

Ref. No. ……………… **Date …………………..**

CERTIFICATE

To,

The Registrar
Banaras Hindu University
Varanasi - 221005 India

Through: The Head, Department of Agronomy

Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of nutrient management through FYM and bio-inoculants in mungbean [*Vigna radiata* (L.) Wilczek] under custard apple (*Annona squamosa* L.) based Agri-horti system"** submitted by **Ms. Monika Jaiswal**, **ID No. 17430AGF012, Enrolment no. 401476** in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Agroforestry** of the Banaras Hindu University and placing on record that she has completed the requisite requirements as contained in the statutes of the University.

I certify that the entire scheme of investigation reported 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 have not been utilized for the award of other degree or dissertation.

Thanking you.

Your's faithfully

Forwarded By

(Ramesh Kumar Singh)
Supervisor

Head

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INDIA

ID. No. 17430AGF012 **2019** **Enrolment No. 401476**

APPROVED BY ADVISORY COMMITTEE

Supervisor **Dr. Ramesh Kumar Singh**
Professor
Department of Agronomy, B.H.U., Varanasi.

Co-Supervisor **Dr. Sant Prasad**
Professor
KVK, R.G.S.C., B.H.U., Mirzapur

Member **Dr. Savita Dewangan**
Assistant Professor (Agroforestry)
R.G.S.C., B.H.U., Mirzapur

Member **Dr. Triyugi Nath**
Assistant Professor
Department of Soil Science & Agril. Chemistry, B.H.U., Varanasi.

External Examiner

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Date:
Place: BHU, Varanasi *(Monika Jaiswal)*

CONTENTS

ABBREVIATIONS AND SYMBOLS USED

%	:	percentage
°C	:	degree Celsius
@	:	at the rate of
-1 or /	:	per
Cm	:	Centimeter
d. f.	:	degree of freedom
DAS	:	Days after Sowing
dS m^{-1}	:	Deci Siemens per meter
et al.	:	and others
Fig.	:	Figure
FYM	:	Farm Yard Manure
g	:	gram
Ha	:	hectare
i.e	:	that is
K	:	Potassium
Kg	:	kilogram
m	:	meter
Max.	:	Maximum
mg	:	milligram
Mha	:	million hectares
Min.	:	Minimum
mm	:	millimeter
N	:	Nitrogen
NS	:	Non Significant
P	:	Phosphorus
PSB	:	Phosphate solubilizing bacteria
RBD	:	Randomized Block Design
Rh	:	*Rhizobium*
Sem±	:	Standard Error (Mean)
Viz	:	namely

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Chapter I

INTRODUCTION

Agroforestry is a collective name for land-use schemes and techniques where woody perennials (trees, shrubs, bamboos, palms etc.) are intentionally used in the same land-management units as arable crop and/or livestock, in some type of spatial structure or temporal sequences, and there are both ecological and economic interactions between the different components. Agroforestry is generally practiced with the objective of developing a more sustainable form of land use that can improve farm productivity and beneficial for the rural community. Agroforestry has both productive and protective functions. Among the productive functions, the five 'Fs' (food, fodder, fruit, fuel, fibre) are important also wood, gums, resins, medicines and greater food security. It is a land use system which besides tangible benefits provides no tangible benefits like ecosystem services viz. soil enrichment, carbon sequestration, biodiversity conservation, air and water quality (Jose *et al.*, 2009).

Trees and crops both strongly compete for sun light where shade effect resulting from the tree crown adversely influence the productivity potential of annual crop (Srinivasan *et al.*, 1990). In the World India is the first country to adopt the National Agroforestry Policy in 2014 (Bijalwan *et al.*, 2017). Estimated land area of 1,023 million ha is under agroforestry worldwide. In India total forest land is 21.3 percent of the total geographical area. The current area under agroforestry in india is estimated as 25.32 m.ha. (Dhyani *et al.*, 2013).

Agri-horti system is one of the important components of agroforestry in which the combination of fruit crops in croplands is practiced. Aonla, ber, guava, custard apple, citrus etc. are major favourable fruit crop suitable for agri-horti system. It is an improved indigenous cropping system in India for full utilization of the growing season and increasing the return per unit area per unit time. Fruit crops are first preference of farmers under agroforestry system on account of short gestation period, regular income, risk cover and aesthetic value (Anonymous, 2000).

Custard apple (*Annona squamosa* L.) is distributed throughout the tropics and is pre-eminently a desert fruit, normally eaten fresh. The content of vitamin C is noticeable (35-42 mg/100 g). The nutrient value of custard apple (thiamine, calcium, magnesium, potassium and dietary fiber) is also found sufficient amount. The tree is a good source of fruits, firewood, seeds and leaves have effective vermicidal and insecticidal properties. Leaves, roots, shoots, and bark have been reported to have medicinal properties. The unripe fruit is an astringent, and the root is a laxative. It can be planted as a shade tree and also suitable for growing with short duration arable crops.

Pulses are the main source of protein mainly for vegetarians and contribute about 14% of the total protein of an Indian average diet. India is the world's largest pulse growing country which covers about 23.0 m ha area and producing about 23.95 m tons pulses with productivity 694 kg ha^{-1}. India is the largest producer of mungbean, the third largest pulse crop accounts for 15 per cent (3.5 m ha) of the national pulse crop area and 8.5 per cent (1.2 million ton) of total pulse production in the country (IIPR, 2011). In India, mungbean is cultivated in the state of Rajasthan, Madhya Pradesh, Punjab, Haryana, U.P., Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Mungbean (*Vigna radiata* L.) is an important pulse crops having high nutritive value. It can be grown twice in a year, both in spring and autumn seasons, in irrigated as well as rainfed areas (Malik *et al.*, 2001). Mungbean due to its ecological versatility it is widely cultivated in various climate and geographical regions of India (Tripathi *et al.*, 2012) and found to be most feasible crop to be introduced under agri-horti system. It is not only plays an important role in human diet but also in improving the soil fertility by fixing the atmospheric nitrogen (Nadeem *et al.*, 2004). An significant characteristic of the mungbean plant is its capacity to create a symbiotic relationship with particular bacteria, establishing the biological N2 fixation in root nodules that supply the nitrogen requirements of the plant. It has been reported that the net benefits of legumes are often equivalent to the addition of 50-100 kg N ha^{-1} as fertilizer. Mungbean is an excellent source of protein (24.5%) with high quality of lysine (460 mg/g N) and tryptophan (60 mg/g N). It contains also remarkable quantity of ascorbic acid and riboflavin (0.21mg /100 g). (Azadi *et al.*, 2013)

FYM is one of the ancient manure used by the farmers in growing crops due to rich organic matter and a good source of plant nutrients and its easy availability and presence of all the nutrients required by the plants. Farm yard manure refers to the decomposed mixture of dung and urine of farm animals along with their litter and left over material from forage or fodder fed to the cattle. On decomposition, it produces organic acids and carbon-dioxide, which help to dissolve minerals and make them more available to the growing plants. FYM also acts as a source of energy for the growth of soil micro-organisms. It improves the physical, chemical and biological conditions of the soil. Improvement in physical properties of the soil, organic carbon and available nitrogen, phosphorus and potassium has been well documented by Babulkar *et al.* (2000) due to long term application of FYM and fertilizers. Application of FYM to farm crops also avoids its wasteful use for burning purposes.

Nutritional status of FYM (%)

Nitrogen	0.5
Phosphorus	0.25
Potassium	0.4
Calcium	0.08
Sulphur	0.02
Zinc	0.004
Copper	0.0003
Manganese	0.007
Iron	0.45

Biofertilizers are known to play an important role in increasing biological fixation of atmospheric nitrogen and enhance phosphorus availability to crop (Bhat *et al.*, 2013). The bio-fertilizer or microbial inoculants can be generally defined as a substance which contains living microorganisms which when applied to seed, plant surfaces, or soil colonizes the rhizospehere or the interior of the plant and encourages growth by increasing the availability of primary nutrients to the host plant (Mazid *et* *al*., 2011). They are often used for composting the area with the aim of increasing the number of such micro-organisms and quicken microbial activities to boosting the extant of the availability of the nutrient in a form which can easily assimilated by plant. (Subba-Rao, 1986).

The *Rhizobium* as fertilizer in pulses could fix 50-200 kg of N ha^{-1} $season^{-1}$ and is able to meet 80-90 percent of the crop requirement for nitrogen. Inoculation in these crops was found to increase the crop yield by about 10-15per cent under on farm conditions. Inoculation of seed with rhizobium culture is low cost technique in legumes and has been found beneficial in boosting up production (Bhat *et al*., 2013).

The phosphorus present in soil become unavailable to plants due to its chemical fixation, thus favouring inoculation with phosphate solubilizing bacteria (PSB). The role of microorganisms in solubilizing inorganic phosphates in soil and making them available to plants is well known. PSB solubilize the insoluble phosphate in soil, making Phosphorus available to plant. The mechanism of action of these micro-organisms involves secretion of organic acids which lower the P^H and increase the availability of sparingly soluble phosphorus sources. The nutrient requirement of crop is met by the chemical fertilizers. However, fertilizer alone cannot sustain productivity of land in modern farming. Similarly, the supply of nutrients through organic manures and bio-fertilizers can hardly meet a crop's need. The *Rhizobium* + PSB inoculation had positive effect on grain Yield of Black gram (*Vigna mungo* L.) which was slightly higher than obtained with either *Rhizobium* or PSB separately (Hussain *et al*., 2011).

Nitrogen is an important major nutrient element for plant. For legumes, it is more useful because it is the main component of amino acids as well as proteins. Adequate supply of nitrogen is essential for normal growth and yield. It imparts green colour to leaves and stems and enable them for efficient photosynthesis. Therefore, a starter dose of nitrogen is essential to meet the initial nitrogen requirement of the plants. Its requirement of pulses is very low because after establishment plant fulfill their requirement through symbiotic nitrogen fixation. In legumes, the symbiotic relationship with rhizobia is responsible for fixing the equivalent of 30-40 kg of nitrogen on an average whole plant basis (shoots and nodulated roots). Consequently, factors that directly influence legume growth (availability of water and nutrients).

Phosphorus is the second most essential nutrient after the nitrogen. Its requirements vary depending upon the nutrient content of the soil. Phosphorous has referred to as the *"Master key element"* in crop production. Phosphorus deficiency restricts the plant growth and remains immature. Common analytical properties of phosphorus deficiency are a darker green leaf colour due to higher chlorophyll contents, reduced leaf extension and a higher root-to-shoot ratio, since root growth is Much less affected by phosphorus deficiency than shooting growth. Most of the phosphorous present in soil is unavailable to plants which are made available by action of efficient micro-organism like bacteria, fungi, and even *cyanobacteria.*

Potassium is the third important nutrient required for plant. In rainfed conditions Potassium availability is generally low to medium. In plants potassium plays an important role for the growth and development. It increases photosynthesis, decreases respiration, and helps in transport of sugar and starch plant growth, after nitrogen and phosphorus. Potassium helps plants to adjust low water potential under stress from drought. In drought, it maintains the turgor of the plant cell and controls stomatal.

Keeping these facts into consideration the present investigation entitled "Effect of nurtient management through FYM and bio-inoculants in mungbean (*Vigna radiata* (L.) Wilczek) under custard apple (*Annona squamosa* L.) based Agri-horti system" was conducted with following objectives:

1. To find out the effect of fertility levels and bio-inoculants on growth and yield of mungbean under custard apple based Agri-horti system.
2. To find out the effect of treatments on nutrients content and uptake by crop.
3. To work out the economics of different treatments.

REVIEW OF LITERATURE

In review of literature we find out the effect of nutrient management through FYM and bio-inoculants on growth and Yield of mungbean (*Vigna radiata* (L.) Wilczek). Farming of agricultural crop along with fruit trees (Agri-horticulture) is a special and unique practice. Custard based Agri-horti system may play an important role in Vindhyan region.

An attempt has been made in this chapter to review the literature availability in the country and abroad with respect to **"Effect of nutrient management through FYM and bio-inoculants in mungbean (*Vigna radiata* (L.) Wilczek) under custard apple (*Annona squamosa* L) based Agri-horti system".** Various aspects of FYM, *Rhizobium*, PSB and economics are presented below.

2.1 EFFECT OF CHEMICAL FERTILIZERS (NPK)

2.1.1 Growth parameters

Chattopadhyay and Dutta (2003) observed at Majhian (W.B.) that application of 80 kg P_2O_5 ha^{-1} along with basal dose of 20 kg N + 40 kg K_2O ha^{-1} significantly increased the number of nodules and weight of nodules $plant^{-1}$ in cowpea at flowering stage over lower levels of phosphorus.

Kumar *et al.* (2003) conducted an experiment at Lakhoti reported that mungbean fertilized with 20 kg N + 40 kg P_2O_5 ha^{-1} significantly increased the growth parameters as compared to control.

Singh and Pareek (2003) reported from their experiment on mungbean in loamy sand soil at Jobner that application of 30 kg P_2O_5 ha^{-1} along with basal dose of 25 kg N ha^{-1} significantly increased plant height, number of branches $plant^{-1}$, number of nodules $plant^{-1}$, weight of nodules $plant^{-1}$ and length of pod compared to 15 kg P_2O_5 ha^{-1} and control.

Chettri and Mondal (2004) reported from Mohanpur that in blackgram crop application of 30 kg K_2O ha^{-1} along with basal dose of 20 kg N + 40 kg P_2O_5 ha^{-1} produced maximum dry matter accumulation.

Luikham *et al.* (2005) evaluated at Imphal and application of 60 kg P_2O_5 ha^{-1} along with basal dose of 20 kg N + 30 kg K_2O ha^{-1} and recorded significantly higher dry matter production and number of branches $plant^{-1}$ in greengram.

Karwasra *et al.* (2006) conducted a field experiment on greengram at Hisar and observed that the plant height and number of branches $plant^{-1}$ were increased significantly with increasing levels of phosphorus up to 50 kg P_2O_5 ha^{-1} along with basal dose of nitrogen 20 kg N ha^{-1}.

Srinivasarao and Ali (2006) in a field experiment on uradbean and mungbean at Kanpur noted that root and shoot biomass was significantly higher with optimum nutrient supply (20 kg N +60 kg P_2O_5 ha^{-1} + 20 kg K_2O ha^{-1}) over control.

Biswas and Patra (2007) observed that application of 40 kg P_2O_5 ha^{-1} with soil inoculation of VAM and seed inoculation with PSB recorded higher canopy height. Dry matter accumulation, LAI, CGR, NAR and nodulation in summer greengram than that of control lower dose of Phosphorus.

Koushal and Singh (2011) performed an experiment at Agriculture College Farm, Amritsar and observed that the application of 50% recommended N applied through urea + 50 % N through FYM + PSB, the maximum plant height of 16.89 cm, 65.78cm, and 73.37 cm at 30, 60 and 90 DAS, the highest number of pods per plant (80.40) and test weight (17.02 g) of soybean crop.

Khan *et al.* (2017) studied the effect of phosphorous levels on the relative yield of kharif mungbean (*Vigna radiata* (L.) Wilczek). It constitute of four levels of phosphorous levels viz., 15 kg P_2O_5 ha^{-1} , 30 kg P_2O_5 ha^{-1}, 45 kg P_2O_5 ha^{-1}, and control (no phosphorous application). Results indicated that most growth characteristics such as plant height, number of branches $plant^{-1}$, dry weight of root, stem, leaf and total dry weight were significantly increased due to application of phosphate fertilizer (45 kg P_2O_5 ha^{-1}) over control.

Verma *et al.* (2017) conducted an experiment on mungbean crop the experiment with four levels of recommended dose of fertilizers (RDF) i.e. (0, 75%, 100%, 125% RDF) and recorded that the highest grain yield (524 kg ha^{-1}), straw yield (1425 kg ha^{-1}) and biological yield (1949 kg ha^{-1}) under the application of 100% RDF (20:40:20 NPK kg ha^{-1}).

2.1.2 Yield attributes and Yield

Sardana *et al.* (2006) observed at Ludhiana that application of 12.5 kg N +30 kg P_2O_5 ha^{-1} in lentil noted in an increase of 6.6% and 9.2% higher seed and straw yield respectively, than 12.5kg N + 20 kg P_2O_5 ha^{-1} which in turn, increased the mean seed yield by 18.7% and straw yield by 29.4% over application of 6.25 kg N +10 kg P_2O_5 ha^{-1}.

Pandya and Bhatt (2007) conducted an experiment at Anand on fodder cowpea and obtained that application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} along the FYM @ 25t ha^{-1} recorded significantly higher green and dry matter yield.

Singh and Sekhon (2007) performed an experiment on greengram at Ludhiana and observed that the application of 12.5 kg N + 40 kg P_2O_5 ha^{-1} reported that the number of pods $plant^{-1}$, 1000 seed weight and biological yield were found significantly more than lower dose.

Seed inoculation + 15 kg N ha^{-1} recorded that the significantly increased the maximum number of pods $plant^{-1}$ (20.67), number of seeds $plant^{-1}$ (191.90), 100- seed weight (4.46 g) and seed yield (5.01 $plant^{-1}$) of mungbean crop **(Anjum *et al.*, 2006)**.

Asaduzzaman *et al.* (2008) evaluated the effect of nitrogen and irrigation managements on dry matter accumulation and yield of mungbean (*Vigna radiata L.)* at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The result showed that the application of 30 kg N ha^{-1} as basal with one irrigation at flower initiation stage

(35 DAS) significantly increased the number of pods $plant^{-1}$ (43.30), number of seeds $plant^{-1}$ (10.46) and 1000-seed weight (46.23 g) and maximum seed yield $plant^{-1}$ (5.53 g) or per hectare (1.65 t) compare to other treatments.

Sammauria *et al.* (2009) reported that 15 kg N + 30 kg P_2O_5 ha^{-1} significant increase the number of pods $plant^{-1}$, seeds pod^{-1}, seed and biological yield of clusterbean than lower levels of fertilizers.

Sadeghipour *et al.* (2010) investigated the effects of different nitrogen and phosphorus levels on yield and yield components of mungbean at the Shahre-rey, Islamic Azad University Research Farm in Tehran. Result showed that significant increase the seed yield due to the application of 90 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} over lower rates of fertilizers. Increase in yield attributes to more number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seeds weight.

Choudhary and Yadav (2011) conducted a field experiment on loam sand at Jobner (Rajasthan) reported that application of 20 kg N + 40 kg P_2O_5 ha^{-1} two cowpea produced significantly higher dry matter per meter row length, number of branches $plant^{-1}$, plant height total chlorophyll content and number and weight of root nodules $plant^{-1}$ compared with lower doses of N and P.

Hossain *et al.* (2011) studied the effect of *Rhizobium* inoculation and fertilization on the yield and yield component of mungbean and reported that the application of 45 kg N + 80 kg TSP +55 kg MOP ha^{-1} with *Rhizobium* inoculation (1.5 kg ha^{-1}) recorded more number of pods $plant^{-1}$ (20.87), pod length (8.71 cm), number of seeds pod^{-1} (8.53), 1000 seeds weight (27.82 g), seed yield (1.40 t ha^{-1}) and harvest index (28.57%) over the control.

Armin *et al.* (2012) recorded maximum number of pods $plant^{-1}$ (25.13), number of seeds pod^{-1} (14.87), 1000-seed weight (41.95 g) and maximum seed yield (1156.19 kg ha^{-1}) due to the application of vermicompost + 100 % of optimum dose of inorganic fertilizer.

Chaudhari *et al.* (2016) conducted a field experiment during *rabi* season of 2013-14 at Navsari Agricultural University and observed that the application of 40 kg P_2O_5 ha^{-1} , Significantly increased seed yield (852.42 kg ha^{-1}) and straw yield (1670.5 kg ha^{-1}) over the control.

Umrao *et al.* (2016) studied the effect of NPK levels in combination with *Rhizobium* and PSB culture on growth and yield of green gram (*Vigna radiata* L. Wilczek) raised in the Subabul (*Leucaena leucocephala)* based agroforestry system. Result showed that the application of 30-30-15 kg NPK ha^{-1} + dual seed inoculation of *Rhizobium* and PSB culture significantly increased the number of pods $plant^{-1}$ (22.87) and number of grains pod^{-1} (11.76) compared to all other treatments.

Jangir *et al.* (2016) carried out a field trial during kharif season and observed that the application of 100 % RDF (20 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}) significantly increased the seed yield (1112.54 kg ha^{-1}) and straw yield (1384.2 kg ha^{-1}) of black gram over the control.

2.1.3 Nutrient content, uptake and quality

Krishna *et al.* (2001) conducted a field experiment on chickpea at Kanpur and reported that application of 30 kg N ha^{-1} along with phosphorus (40 kg P_2O_5 ha^{-1}) gave significantly higher nodules and nitrogen uptake over lower doses of nitrogen.

Mondal *et al.* (2005) observed that application of 60 kg P_2O_5 ha^{-1} along with basal dose of N and K (30 kg N + 40 kg K_2O ha^{-1}) significantly increased NPK uptake by greengram.

Yakadri *et al.* (2004) performed an experiment at Rajendra nagar (Hyderabad) and found that application of 20 kg N + 60 kg P_2O_5 ha^{-1} recorded significantly higher nitrogen and phosphorus uptake as a result of higher seed and straw yield of greengram.

Srinivasarao and Ali (2006) conducted a field study on urdbean and mungbean at Kanpur and reported that application of 20 kg N + 60 kg P_2O_5 + 20 kg

K_2O ha^{-1} significantly increased N and P content and uptake by grain and straw over lower doses of fertilizers or control.

Sharma and Abrol (2007) reported that application of 40 kg $P_2O_5ha^{-1}$ along with basal dose of 60 kg N + 40 kg K_2O ha^{-1} significantly increased the phosphorus concentration in grain and straw of chickpea.

Sasode *et al.* (2008) observed at Ganjbasoda that application of 37.5 kg N + 90 kg P_2O_5 + 5.0 kg Zn ha^{-1} significantly increased protein content and uptake of nutrients (N,P,K,S, and Zn) in seed of greengram over lower levels of fertilizers.

Gupta *et al.* (2009) conducted an experiment at sehore (M.P.) and reported that application of 40 kg P_2O_5 ha^{-1} through DAP along with basal dose of 20 kg N ha^{-1} recorded significantly more Nitrogen and Phosphorus uptake by chickpea over lower levels of P_2O_5.

2.2 EFFECT OF FYM

2.2.1 Growth parameters

Ghanshyam *et al.* (2010) conducted an experiment during *kharif* and *rabi* for 2 consecutive years, at Hisar to evaluated the direct and residual effect of organic manures and phosphorus on productivity, nutrient uptake, soil fertility and economics of greengram-wheat cropping system. Result showed that the application of vermicompost and FYM @ 5 ton ha^{-1} noted that significantly higher plant height, root nodules $plant^{-1}$ of green gram over no organic manure.

Singh *et al.* (2010) observed that the application of FYM @ 5 t ha^{-1} on chickpea crop noted significantly improved the growth attributes such as plant height, secondary branches $plant^{-1}$.

Singh *et al.* (2011) investigated that the application of lime + FYM + 50% NPK significant improved the growth attributes of groundnut over control.

Mahatele *et al.* (2011) conducted an experiment during kharif season at Chitrakoot (M.P.) observed that growth and yield attributes nodules plant^{-1}, nodule dry weight Plant^{-1}, primary branches plant^{-1} of pigeon pea were found significantly higher with the application of FYM (10 t ha^{-1}) over control.

Chaturvedi *et al.* (2012) observed that application of FYM, boron and Iron along, with (50% and 100% recommended dose of NPK) significantly increased the number of nodules, dry weight of nodules plant^{-1} and leghaemoglobin content at 60 DAS of soybean crop over control.

Ram *et al.* (2013) conducted a field experiment during post rainy season at Navsari, Gujrat recorded that the application of FYM @ 5 t ha^{-1} on green gram statistically higher growth and yield attributes over no FYM application.

Meena *et al.* (2016) reported that the application of $N_{20}P_{40}K_{40}$ + FYM @10 t ha^{-1} and *Rhizobium* recorded the maximum plant height 50.66 cm, number of leaves plant^{-1} 33.00, number of branches plant^{-1} 4.66 at 60 DAS and number of cluster plant^{-1} 9.33 were found significant over all other treatment.

2.2.2 Yield attributes and Yield

Singh *et al.* (2008) observed that the application of FYM significantly higher grain yield. The increase in grain yield of chickpea crop was 6.5 and 13.3 % higher over control with the application of FYM @ 5 t ha^{-1}.

Pandya *et al.* (2009) reported that the highest green and dry matter yield of fodder cowpea under 150% NPK+FYM which were at par with 100% NPK +FYM treatment**.**

Chaturvedi *et al.* (2012) found that yield attributes of soybean pods plant^{-1}, seeds pod^{-1} and 100 seed weight were increased significantly with the addition of micronutrient and FYM at both the fertility levels (50% and 100% NPK).

Chesti and Ali (2012) performed a field experiment during two succeeding *kharif* seasons, to evaluate the rhizospheric micro flora, nutrient availability and yield of greengram as influenced by organic manures, PSB and phosphorus levels in alfisols. Result discovered the application of organic manures FYM @ 10 t ha^{-1} significantly increased the grain and straw yield of greengram and showed significantly superior treatment.

Patel *et al.* (2016) conducted a field experiment during *kharif* season at Sardarkrushinagar, on Meha variety of mungbean crop fertilized with 75% RDF (20:40:0kg NPK ha^{-1}) + 2t FYM ha^{-1} along with seed inoculation of *Rhizobium*+ PSB recorded maximum seed yield (656 kg ha^{-1}) and Stover yield (1693 kg ha^{-1}) over other combination and sole application of organic and inorganic source of nitrogen.

Girijesh *et al.* (2018) studied the effect of varied levels of FYM on Yield of pulses (black gram, green gram, cowpea and Field bean). Observed that yield of three years was significantly higher with FYM application @ 10.0 t ha^{-1} in blackgram (743 kg ha^{-1}) and mungbean (664 kg ha^{-1}) while it was with 7.5 t ha^{-1} in field bean (655 kg ha^{-1}) and 5 t ha^{-1} in cowpea (1527 kg ha^{-1}) over no FYM treatment.

2.2.3 Nutrient content, uptake and protein content

Ramesh *et al.* (2006) performed an experiment at Bhopal with the application of different organic manures (cattle dung @ 4 t ha^{-1}, vermicompost @ 3 t ha^{-1} and poultry manure @ 2 t ha^{-1}) to pigeonpea crop and obtained highest protein content 21.25% in seed under the treatment application of cattle dung followed by vermicompost (20.90% protein content) and poultry manure (20.87% protein content).

Singh *et al.* (2008) observed that protein content in grain and protein yield of chickpea crop increased significantly due to FYM. Significantly higher protein content was recorded with the application of FYM @ 5 t ha^{-1} over control.

Pandya *et al.* (2009) reported that the application of 150% NPK+ FYM proved to be the best for getting the highest N and K content as well as uptake of cowpea crop over control.

Chesti *et al.* (2012) conducted a field experiment during two consecutive *kharif* season to evaluate the effect of organics and Phosphorus sources on quality of green gram in temperate conditions of J&K. The results showed that application of organic manures significantly improved the protein content and total soluble sugars in grain of green gram. Among organic manures application of FYM @ 10 t ha^{-1} found significantly superior over the treatment of Dalweed (15 t ha^{-1}).

Chaudhary *et al.* (2016) studied the effect of FYM, phosphorus and PSB on nutrient content and uptake by cowpea (*Vigna unguiculata* (L.) Walp) on loamy sand. The application of FYM @ 10 t ha^{-1} recorded that significantly maximum N, P and K content in seed (3.797, 0.615 and 1.74%) and stover (0.675, 0.235 and 2.54%) and total N, P and K uptake by 10 t ha^{-1} FYM (F_1) was 9.92, 17.96, and 21.81 percent higher than 0 t ha^{-1} FYM (F_0).

Rekha *et al.* (2018) evaluated the effect of two FYM levels *viz*., 0 t FYM ha^{-1} and 10 t FYM ha^{-1} and seven treatments of phosphorus *viz*., only PSB, 20 kg P_2O_5 ha^{-1}, 20 kg P_2O_5 ha^{-1}+PSB, 30 kg P_2O_5 ha^{-1}, 30 kg P_2O_5 ha^{-1} + PSB, 40 kg P_2O_5 $ha^{-1}$and 40 kg P_2O_5 ha^{-1} +PSB on growth, yield and economics of greengram [*Vigna radiata* (L.) Wilckzek]. Result showed that the maximum N, P and K content in grain and stover (3.67%, 0.505%) (0.598%, 0.198%), (1.58%, 2.80%) respectively. It is also increased the uptake of N, P and K by grain and stover (26.78 Kg ha^{-1}, 7.05 Kg ha^{-1}), (4.38 Kg ha^{-1}, 2.84 Kg ha^{-1}), (11.38 Kg ha^{-1}, 39.73 Kg ha^{-1}) due to the application of 40 kg P_2O_5 ha^{-1} + PSB.

2.3 EFFECT OF BIO-INOCULANTS ON GREEN GRAM

2.3.1 Growth parameters

Srivastava and Ahlawat (1995) observed that combined inoculation of pea seeds with *Rhizobium* and PSB significantly increased growth attributes plant height, dry matter accumulation, nodules per plant, dry weight of nodules in pea by 11.4, 8.0, 28.4 and 26.4 percent, respectively over the control.

Balamurugan and Gunasekaran (1996) found that combined inoculation of *Rhizobium* + PSB in groundnut significantly increased plant dry weight and nodulation by 61.3 and 54.0 percent, respectively over the control.

Rasal *et al.* (1996) reported that greengram seeds inoculated with *Rhizobium* + PSB along with recommended phosphorus fertilizer recorded the highest number and dry weight of nodules per plant.

Chandra and Pareek (2007) conducted an experiment on sandy loam soil at Pantnagar reported that inoculation of mungbean variety 'Pant Mung 2' with seed inoculation carrier based and liquid inoculants were comparable and significantly favoured the number and dry weight of root nodules in both the years, recording mean increase of 25.2 to 40.5 percent and 47.3 to 38.7 Percent over the un inoculated control.

Vikram *et al.* (2008) observed that inoculation of green gram seeds with PSBV-14 recorded the highest nodule number, nodule dry weight, shoot dry matter and total dry matter in green gram plants 45 days after sowing. Similarly, treatment receiving the inoculation of PSBV-13 noted the highest root length, root dry matter, Phosphorus content and P uptake in root and shoot in green gram plants.

Selvakumar *et al.* (2009) conducted a field experiment and found that the combined inoculation of *Rhizobium* + phosphobacteria significantly increased the Plant growth and yield of blackgram compared with control (without biofertilizers).

Hussain *et al.* (2011) observed that the combined inoculation of *Rhizobium* + PSB slightly improved plant height, dry matter production, number and weight of nodules per plant of black gram (cv. Pant Urd-19) over *Rhizobium* and PSB inoculated separately.

Koushal *et al.* (2011) performed a field experiment at Agriculture College Farm, Amritsar. To studied the impact of integrated nutrient management in soybean on residual fertility status of soil. Result envisage that the application of the treatment 50 % recommended N applied through urea + 50 % N through FYM + PSB, recorded maximum plant height of 16.89 cm, 65.78 cm, and 73.37 cm at 30, 60 and 90 DAS, and the lowest of these were found in the control treatment.

Kundu *et al.* (2013) conducted a field experiment at Bidhan Chandra Krishi Viswavidyalaya on Gangetic alluvial soil of West Bengal. To investigated the effect of seed inoculation (*Rhizobium*) with different nutrient sources on the nodulation and yield of mungbean in Factorial RBD with three replications. Observed that the *Rhizobium* seed inoculation positively and significantly influenced the growth parameter and nodulation of mungbean under *Rhizobium* inoculation coupled with the application of recommended dose of NPK.

Patel *et al.* (2013) observed that dual inoculation of *Rhizobium* and PSB on green gram significantly increased the growth attributes such as plant height (57.14 cm), number of nodules plant^{-1} (28.29), number of branches plant^{-1} (3.72), dry matter accumulation plant^{-1} (18.53 gm) which was higher than other treatment.

Zadode *et al.* (2013) performed an experiment on PKV-TARA pigeonpea in *Kharif* season at Akola and observed that the application of 5 t FYM ha^{-1} with combined inoculation of biofertilizer (*Rhizobium* + PSB + PGPR) increased the plant height, number of branches plant^{-1}, dry matter accumulation and number of nodules plant^{-1} over the all other treatment.

Dongare *et al.* (2016) carried out an experiment during summer at Latur (Maharastra) observed that the combined inoculation of *Rhizobium* and PSB with the 100% RDF significantly increased the plant height (32.21 cm) and growth attributes over the alone seed inoculation of *Rhizobium* (30.57 cm) and alone seed inoculation of PSB (27.99 cm).

Kant *et al.* (2016) observed that the combined inoculation of *Rhizobium* and PSB with the 75 kg P_2O_5 ha^{-1} significantly increased the plant height, number of branches plant^{-1}, nodulation, dry matter accumulation plant^{-1} compared to all other treatments of blackgram crop.

Seerat un Nissa *et al.* (2017) conducted an experiment during *kharif* season for the two consecutive years at the crop research farm, SKUAST-K. Observed that the application of bio-fertilizer (*Rhizobium*) with Phosphorus @ 60 kg ha^{-1} showed the best result significant effect on plant height (cm), No of branches $plant^{-1}$, No of leaves $plant^{-1}$ and No of nodules $plant^{-1}$ over the control.

2.3.2 Yield attributes and yield

Nadeem *et al.* (2004) found that the number of pods $plant^{-1}$ were significantly also effected by seed inoculation with *Rhizobium* in green gram and also significantly increased the higher number of pods $plant^{-1}$ than un-inoculated seeds.

Vijla and Jebaraj (2008) observed that the combined inoculation of *Rhizobium* + PSB in greengram significantly improved number of pods $plant^{-1}$, seeds pod^{-1} , 1000 seed weight Over *Rhizobium* and PSB inoculated separately.

Kachhave *et al.* (2009) conducted an experiment with dual inoculation of Rhizobium and PSB with recommended dose of chemical fertilizer found beneficial in black gram over single use of bio-fertilizer and dual inoculation of bio-fertilizer increased the grain yield either with or without chemical fertilizer.

Amitesh Kumar Singh and R.S. Singh (2011) studied the response of phosphorus levels (control, 25, 50 and 75 kg P_2O_5 ha^{-1}) and bioinoculants (untreated control, PSB, PGPR and PSB + PGPR) on mungbean and observed that the dual inoculation of PSB + PGPR produced maximum yield attributes *viz.* pod length (cm), pods $plant^{-1}$, pod weight $plant^{-1}$ (g), grains pod^{-1}, 1000-grain weight and yield found significantly superior over sole application of PGPR, PSB and control.

Hussain *et al.* (2011) reported that *Rhizobium* + PSB inoculation produced maximum seed yield (8.82 q ha^{-1}) which was slightly higher than either *Rhizobium* or PSB separately (8.18 and 8.80 q ha^{-1}) respectively.

Bhattacharya (2012) observed effect of *Rhizobium* and PSB inoculation on mungbean variety SML-264 in regards to nodulation and grain yield and reported that the seed treatment with dual bacterial cultures increased nodulation rate, Nitrogen content and grain yield over control significantly higher due to *Rhizobium* strain M-10 and AKR-1 seed in combination with PSB containing *Bacillus polymyxa.*

Jat *et al.* (2012) conducted an experiment during summer season on sandy loam soil of central U.P. under irrigated conditions on greengram under rice-wheat cropping system. Both the biofertilizer and organic manure proved to be better over untreated plot in respect of the growth, yield attributes and yield of greengram. The combination of vermicompost @ 2 t ha^{-1} + 100 kg DAP ha^{-1} + inoculation of *Rhizobium* culture proved to be the best and recoded the maximum number of pods $plant^{-1}$ (15.63), seeds pod^{-1} (11.34), Test weight (41.92 g) and maximum grain Yield (1325 kg ha^{-1}).

Kumawat *et al.* (2013) carried out an experiment during *kharif* season. It consisted of thirteen treatment combinations comprising of two phosphorus levels (20 and 40 kg P_2O_5 ha^{-1}), three phosphorus sources (DAP, SSP and PROM), two biofertilizers (PSB and *Rhizobium*) and one absolute control. To evaluate the effect of phosphorus sources, levels and biofertilizers on black gram Seed inoculation with PSB markedly enhanced yield attributes, seed (10.11 q ha^{-1}), straw (20.88 q ha^{-1}), biological (30.98 q ha^{-1}) yields, due to the application of 40 kg P_2O_5 through DAP along with PSB.

Tagore *et al.* (2013) reported that *Rhizobium* and phosphate solubilizing bacterial (PSB) inoculants enhanced all the yield attributing parameters and also increased grain and straw yields.

Chaudhari *et al.* (2016) conducted a field experiment during *rabi* season at Navsari and observed that PSB inoculation and recorded significant increase in the seed and straw yield (830.36 kg ha^{-1}, 1607.70 kg ha^{-1}) respectively.

Kant *et al.* (2016) conducted a field experiment in *kharif* on urdbean observed that the dual inoculation of *Rhizobium* + PSB with the 75 kg P_2O_5 ha^{-1} significantly increased the yield attributes such as number of pods $plant^{-1}$, test weight (g), grain yield, straw yield and biological yield (q ha^{-1}) compared to all other treatments.

Meena *et al.* (2016) found that application of N 20 kg ha^{-1}, P_2O_5 40 kg ha^{-1}, K_2O 40 kg ha^{-1}, FYM @40 t ha^{-1} and *Rhizobium* in mungbean crop increased number of pods $plant^{-1}$ (37.33) and total seed yield (12.10 q ha^{-1}) which was higher than other treatments.

Singh *et al.* (2017) studied the effect of integrated nutrient management for high productivity and net returns in lentil and observed that the highest pods $plant^{-1}$ due to the application of dual inoculation of *Rhizobium* and PSB (RDF + *Rhizobium* + PSB) on lentil crop.

Bhavya *et al.* (2018) observed that the combined application of 100 % RDP along with PSB and vermicompost registered significantly highest grain (1033.33) and halum (1625.66) yield in green gram.

Rekha *et al.* (2018) conducted an experiment at the Sardarkrushinagar, Gujarat observed that the application of 40 kg P_2O_5 ha^{-1} + PSB @ 10 t FYM ha^{-1} crop significantly the higher seed yield (727 kg ha^{-1}) and stover yield (1399 kg ha^{-1}) in greengram crop.

2.3.3 Nutrient content, uptake and quality

Kumawat *et al.* (2009) performed an experiment on mungbean crop. Results showed that the application of vermicompost 2t ha^{-1} , seed inoculation with PSB and 40 kg P_2O_5 ha^{-1}significantly increased the N, P and K concentration in seed, straw, their total uptake and protein content mungbean.

Seema and Singh (2009) conducted an experiment to observed the effect of micronutrients and bio-fertilizer inoculation on grain yield, protein content, micronutrients content and economics of chickpea and concluded the treatment of RDF + *Rhizobium* + PSB gave significantly highest protein content (23.47 per cent) which was 7.31 per cent increased over control.

Dekhane *et al.* (2011) evaluated effect of bio fertilizer and fertility levels on yield, protein content and nutrient uptake of cowpea. Sixteen treatments comprising of four levels of bio fertilizer viz., without inoculation, with PSB inoculation, liquid PSB inoculation and *Rhizobium* inoculation and four fertility levels viz., 0, 50, 75 and 100 % RDF were tried in factorial randomized block design with four replications. Result revealed that the 100% RDF with *Rhizobium* inoculation significantly increased protein and N, P content as well as uptake of N and P by grain and stover.

Prasad *et al.* (2014) studied the effect of *Rhizobium* inoculation and phosphorus levels on performance of mungbean under guava based agri-horti system. The application of the *Rhizobium* inoculation + 60 kg P_2O_5 ha^{-1} were also significantly increased the N and P content and uptake in mungbean crop.

Dhakal *et al.* (2016) carried out an experiment at Varanasi (U.P.) during *kharif* season, to stufdy the influence of integrated nutrient management on greengram [*Vigna radiata* (L.) Wilczek]. Treatment combination of 75% RDF+ 2.5 t ha^{-1} vermicompost + *Rhizobium* + PSB significantly increased in protein content (24.72 percent), NPK content in seed and straw (Nitrogen 3.96, 2.00 percent, Phosphorus 0.483, 0.0284 percent and potassium 1.534, 1.307 percent, respectively) than other combinations and control.

Patel *et al.* (2016) conducted a field experiment in the summer season at Navsari, Gujarat (India). Nutient uptake (NPK) and protein yield was influenced significantly due to different bio-fertilizer treatments. Significantly the highest protein yield (190.20 kg ha^{-1}) and nutrient uptake were recorded under treatment *Rhizobium* + PSB seed inoculation.

Bhavya *et al.* (2018) studied the effects of phosphorus levels, bio fertilizers (Phosphate solubilizing bacteria) and organic manures (vermicompost) on yield, nutrient concentration and their uptake at flowering and harvest of green gram. Result showed that the application of inorganic Phosphorus fertilizers, organic manures and PSB (vermicompost @ 5 t ha^{-1} + PSB + 100% RDP) markedly influenced the nutrient concentration and their uptake. Significantly highest NPK uptake by grain and haulm (39.06, 40.49 kg ha^{-1}), (3.52, 3.62 kg ha^{-1}) and (24.47 and 11.32 kg ha^{-1}) respectively.

2.4 EFFECT OF AGRI-HORTISYSTEM ON ARABLE CROPS

Korwar and Pratibha (1999) conducted an experiment for 2 years on a red loamy sand soil at Hyderabad to evaluate the performance of short duration pulses, viz. greengram, blackgram and cowpea intercropped with African winter thorn *(Faidherbia albida* Del.) trees at 2 densities, viz 625 and 156 plants ha^{-1}. The results indicated that seeds yields of greengram and blackgram were higher under low tree density (156 trees ha^{-1}) than that in sole and under high tree density, whereas cowpea seed yields were lower in both densities under the trees compared to sole crop yields. The equivalent yield and net monetary returns were higher with blackgram monetary returns during both years (Rs.7035, Rs.6416) under low tree density, followed by greengram and cowpea. The results clearly indicate that short duration legumes can be successfully intercropped with *F. albida* at low tree densities.

Menzers *et al.* (2002) studied the competition for water and nutrients between trees and food crops is perhaps one of the most important interaction in agroforestry systems. The yields of intercrops are reduced as the age of trees increases.

Thakur *et al.* (2002) evaluated the effects of different canopy management treatments in 5-year-old *Morus alba* trees on growth potential of urdbean and pea and observed that growth parameters such as plant height, number of branches plant^{-1}, number of flowers plant^{-1} and leaf area index found to have maximum magnitude in the control (without tree) followed by plants under least shade (75 per cent crown removal). The values decreased with increasing shade (less transmission) in both urdbean and pea. Better growth noted on northern aspect than southern aspect.

Yadav *et al.* (2003) observed that plant density in mustard crop declined with increasing tree canopy spread or if decreasing the crop distance from the tree stem in alley cropping system. Increase the spacing and crop distance resulted in better growth of plants. Maximum growth was found in various tree + crop interaction with increased spacing.

Lal and Sharma (2004) found that litchi (*Litchi chinensis*, cv. Rose scented) plantation-based agri-horti system can be raised on degraded gravelly river bed land in Doon valley, Uttar Pradesh with cowpea, okra, sesame, black gram and pigeon pea, as intercrops during the *Kharif* season and toria during the *Rabi* season. On an average, during the *Kharif* season, cowpea and okra produced 20.24 and 29.16 q ha^{-1} of pods while sesame, black gram and pigeon pea produced 2.41, 5.27 and 3.80 q ha^{-1} of grains, respectively. However, toria grown in system with cowpea, okra, sesame and black gram produced 5.00, 3.85, 4.26 and 5.19 q ha^{-1} grains and 18.75, 21.92, 16.70 and 19.25 q ha^{-1} stover yield, respectively during the *Rabi* season.

Datta *et al.* (2007) evaluated the multipurpose tree species (MTP's) in an agroforestry under subtropical humid climate in north-east India. During the initial period up to 8 years of tree establishment, the direct seeding of upland rice, groundnut and sesame were grown which resulted in reduction in crop productivity as compared to open space.

Madhavi Lata *et al.* (2012) found that among the different cropping systems studied in ashwagandha based agri-horticultural system. The yield parameters of ashwagandha were markedly higher under sole cropping system as compared to intercropping both in aonla and terminalia.

2.5 INTERACTION BETWEEN CROPS AND TREE COMPONENTS

Wannawong *et al.* (1991) concluded that when *Eucalyptus*, *Leucaena* and *Acacia* (*A.auriculiformis*) were inter-cropped with green gram, early supplementary and complementary relationships between some system components can suggest synergistic financial gains. Although these biological interactions turn competitive over time, in this case, the gains should be sufficient to make early adopter consider the agroforestry system financially preferable to traditional monocrops.

2.5.1 Competition for light

Thakur *et al.* (2002) observed that the impact of changes in incident radiation through crown modification on crop performance. *Vigna mungo* and *Pisum sativum* crops are grown as field crops with *Morus alba* under rainfed conditions. Different shade intensity created through tree crown management those significantly affected growth, physiological attributes and yield parameters of crops. The crown management treatments, namely, no crown removal, 25, 50 and 75% crown removal resulted in 91, 85, 63 and 47% shade, respectively. Plant height, number of flowers, leaf area of crops reduced significantly with the increase in shade intensities. Higher pods plant^{-1}, grains pod^{-1}, grain yield and harvest index were observed at lower shade intensities. Growth and yield was maximum in open control (without tree); while unmanaged canopy of *Morus alba* caused overall yield reduction of 42%. The maximum photosynthetic rate was observed for open plot plants, which declined in plants beneath dense canopy. The amount of water evaporated from the crop plants decreased with increase in shade intensity. The conversion efficiency was maximum for plants growing as solo crop which decrease with increase in shade intensity. Based on the conclusion, it can be recommended that out of four tree canopy management options, 75% crown removed had the least negative effects on crop growth and yield, thus may be adopted as a compromised crown management practice.

2.5.2 Root and water competition

Singh *et al.* (1998) conducted an experiment and reported that in an alley-cropping trial of *Leucaena* with cowpea, castor, and sorghum under semiarid condition in India, competition for water appeared more important than shading effect.

Jonsson *et al.* (1999) evaluated that microclimate amelioration and enhanced soil fertility may exceed the potentially detrimental influence of shade in the Sahel.

2.5.3 Competition for Nutrient

Costa and Chandrapala (2000) studied the inter species differences in root competition exerted by six trees species (*Calliandra calothyrsus, Gliricidia sepium, Flemingia congesta,Desmodium rensonii,, Cassia spectabilis and Tithonia diversifolia*) on mungbean grown as hedgerow intercrop at pallekelle in the mid-country intermediate zone of Sri Lanka. All intercrops had significantly lower plant nutrient (N, P, and K) content than sole mungbean indicating significant competition by hedges for nutrients. All intercrops showed increases of exchangeable soil potassium and available Phosphorus (expect with *Gliricidia* during the cropping season. It is decided that tree roots of hedgerow intercrops exerted significant competition with the annual crop for absorption of water and nutrients. In this study, *Tithonia* exerted the least competition for water while *Gliricidia* exerted the least competition for nutrients.

2.6 ECONOMICS

Lal *et al.* (2004) found that litchi plantation-based agri-horticultural system can be raised on degraded gravelly riverbed land in Doon valley of Uttarakhand. During the *Kharif* season with cowpea, okra, sesame, black gram and pigeon pea, as intercrops and toria in the *Rabi* season. The highest net profit of 4,554/ha was obtained from okra-toria cropping system followed by cowpea-toria (1,270/ha) and black gram-toria (779/ha) cropping systems with benefit cost ratio of 1.27 %, 1.08 % and 1.05 %, respectively. The plant growth character of litchi was not influenced by any intercrop.

Ram and Kumar (2009) reported that the maximum net returns (13,710/ha) as well as net returns invested (1.52) were obtained by intercropping of *S. hamata* with buffel grass under annona trees mainly due to higher forage yield. Among phosphorus and potash levels, the highest net returns (15,591/ha) and net return invested (1.61) were achieved with application of 60 kg P_2O_5 + 45 kg K_2O ha^{-1}.

Pir *et al.* (2009) recorded highest net profit (18,320 Rs/ha) and B:C (1.34) was recognized with the treatment of 5t FYM ha^{-1} + 30, 50, 30 kg ha^{-1} NPK + *Rhizobium* + PSB.

Beg and Singh (2009) observed that the interaction effect of dual inoculation with *Rhizobium* and PSB under judicious fertility level (20 kg N and 45 kg P_2O_5 ha^{-1}) proved beneficial for boosting seed yield (1182 kg ha^{-1}), and obtained maximum net income (21941 Rs. ha^{-1}) and benefit cost ratio (2.10).

Kumawat *et al.* (2010) conducted a field experiment at Bikaner (Rajasthan) during Kharif season to study the response of mungbean and observed the application of 15 kg N + 20 kg P_2O_5 $^{-1}$ ha significantly increased the net returns and higher B: C.

Jat *et al.* (2012) reported that the application of 100 kg DAP + vermicompost 2 t ha^{-1} + *Rhizobium* culture proved the significantly higher net return of 18,888 RS/ha For greengram crop.

Kumawat *et al.* (2013) carried out an experiment during *kharif* season in 2009. Found that the application of application of 40 kg P_2O_5 through DAP along with PSB. The result showed that highest net return (Rs.24529.87 ha^{-1}) with B: C 2.65 over *Rhizobium* and control of black gram.

Patel *et al.* (2016) conducted a field experiment in kharif season at Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushi Nagar Dantiwada Agricultural University, Sardarkrushi Nagar, to studied the yield and economics of greengram [*Vigna radiata* (L.) Wilczek] cultivars as influenced by integrated nutrient management. Result showed that the maximum gross realization (Rs.40886 ha^{-1}), return net realization (Rs.21763 ha^{-1}) along with higher BCR value 2.14 were recorded (variety Meha) with Combined application of 75% RDF from urea + 2 t FYM ha^{-1} + *Rhizobium* + PSB.

Singh *et al.* (2017) found that the application of RDF + Rhizobium + PSB recorded the highest net returns (Rs. 40321 ha^{-1}) and B: C (3.78).

Girijesh *et al.* (2018) conducted a field experiment for three years in kharif season at Zonal Agricultural and Horticultural Research station, Shivamogga and observed that the higher net returns of Rs.13,013, Rs.10,366, Rs.40,368 and Rs.13,856 with FYM application @ 10.0, 7.5, 5.0 and 2.5 t ha^{-1} for black gram, field bean, cowpea and green gram, respectively.

Chapter III

MATERIALS AND METHODS

The present investigation entitled **"Effect of nutrient management through FYM and bio-inoculants in mungbean (*Vigna radiata* L. Wilczek) under custard apple (*Annona squamosa L.)* based Agri-horti system"** was conducted during *Kharif* season of 2018-19 at Rajiv Gandhi South Campus Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh. The edaphic and climatic conditions under which the experimental crop was raised and materials and techniques employed in conducting the experiment are being described in this chapter.

3.1 LOCATION EXPERIMENTAL SITE

The experiment was carried out at the Agricultural Farm of Rajiv Gandhi South Campus, (BHU) Barkachha, Mirzapur. which is situated in Vindhyan region of district Mirzapur (U.P.) (25° 10' N latitude, 82°37' E longitude and altitude of 427 meters above mean sea level) occupying over an area of more than 1000 ha. Where variety of crops like horticulture, agricultural, medicinal and aromatic plants are grown. Soil type of Barkachha is red lateritic, rainfed and invariably poor fertility status.

3.2 CLIMATE AND WHEATHER

The climate is Barkachha typically semi-arid, characterized by extremes of temperatures in both summer and winter with low rainfall and mild humidity. Maximum temperature in summer is as high as 45˚C and minimum temperature in winter falls below 8.12˚C. The annual rainfall of locality was 847.35 mm in 2018. The rainfall during the experimental period was recorded from the meteorological observatory of the (KVK) Horticultural farm. The total rainfall during the crop season was 96.45 mm; maximum and minimum temperature fluctuated between 45ºC and 26ºC, and relative humidity between 90 and 33 per cent. The metrological data of Mirzapur district is given in Table 3.1 and 3.2.

Table 3.1: Mean month wise meteorological data during crop season *kharif*, 2018-19

Months	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)	
		Max.	Min.	Max.	Min.
January	0.00	28	5	85	12
February	0.00	35	11	92	18
March	0.00	39	15	85	6
April	0.00	43	22	84	8
May	22.95	45	21	86	10
June	42.00	42	25	96	19
July	240.90	38	24	100	38
August	456.30	33	24	97	61
September	85.20	36	24	100	23
October	0.00	37	16	93	15
November	0.00	33	12	88	18
December	0.00	26	5	88	18

Source: Annual Report of the All India Co-Ordinated Research Project on Dry land Agriculture.

Mirzapur falls in a belt of semi-arid to sub humid climate. The normal period for the onset of monsoon in this region is the third week of June and it lasts up to the end of September or sometimes extends to the first week of October. Winter showers are often experienced in between the month of December to mid of February. However, March to May is generally dry. On an average, the major rainfall (75%) is received from June to September. The winter months are cooler whereas summer months are warmer and dry. The hottest and coldest months are May and January respectively.

Table 3.2: Mean week- wise meteorological data during crop season *Kharif*, 2018

Week No.	Months	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sunshine (hrs.)
			Min.	Max.	Min.	Max.	
33	August	22.55	26	33	22	96	5.4
34	August	17.54	24	31	70	96	4.6
35	August	17.54	24	33	68	99	4.2
36	September	17.35	23	32	88	98	4.5
37	September	10.78	24	33	45	92	3.2
38	September	3.74	24	35	41	91	2.3
39	September	6.47	22	36	30	89	2.7
40	October	0	22	37	30	71	2
41	October	0.48	21	36	27	91	2.1
42	October	0	20	36	26	73	2

Source: Krishi Bhawan, Mirzapur

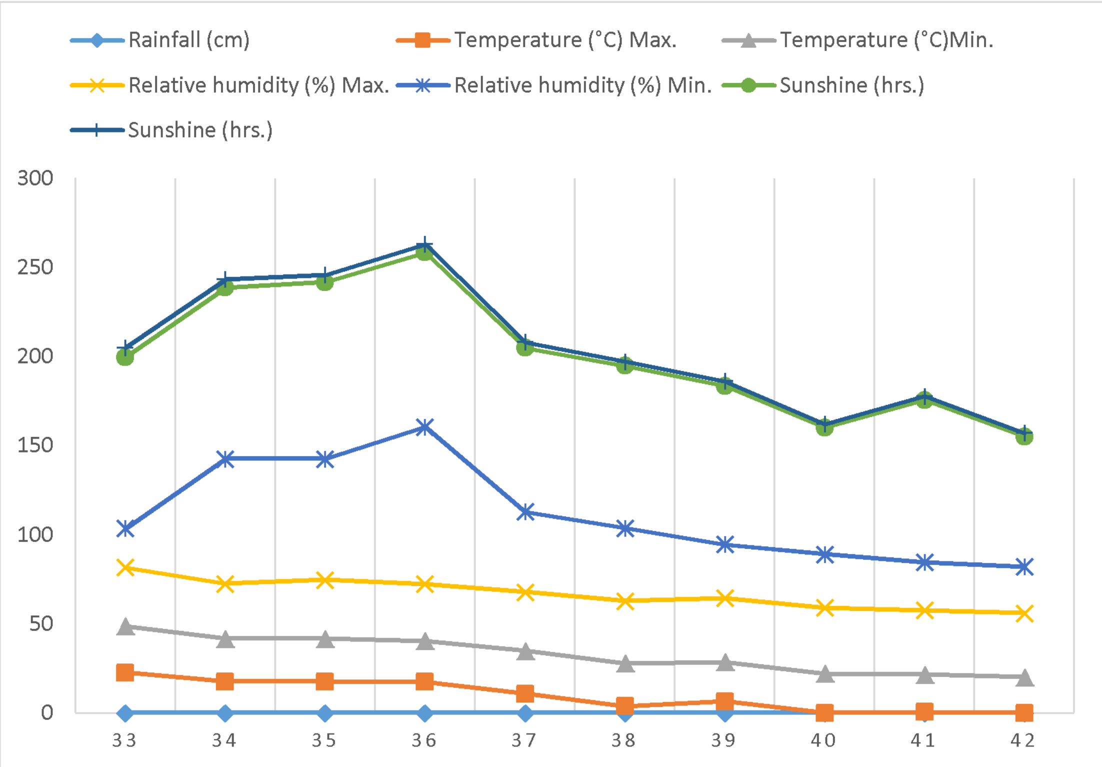

Fig. 3.1. Meteorological graph of mean weather data

3.3 SOIL CHARACTERSTICS OF EXPERIMENTAL FIELD

The soil, as a medium of plant support and growth. Before the experiment was conducted, Soil samples were taken from a depth of 0-20 cm, taking all the possible precautions prescribed for soil sampling. The samples were brought to the laboratory, shade 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: Mechanical and physico-chemical analyses of soil of the experimental field.

Particulars	Value	Rating	Methods	References
Mechanical analyses				
Sand (%)	50.3		Bouyoucos hydrometer	Bouyoucos (1962)
Silt (%)	37.2			
Clay (%)	12.5			
Textural class	Sandy loam		Textural triangle	Black *et al.* (1965)
Physical constants				
Bulk density (mg/m^3)	1.45		Core sampler	Black *et al.* (1965)
Particle density (mg/m^3)	2.65		Pycnometer	
Chemical analyses				
Organic carbon (%)	0.27	Low	Wet digestion method	Walkley and Black (1934)
Available N (kg/ha)	227.6	Low	Alkaline potassium permanganate	Subbiah and Asija (1956)
Available P_2O_5 (kg/ha)	20.55	Low	0.5 M $NaHCO_3$ Extractable	Olsen *et al.* (1954)
Available K_2O (kg/ha)	242.36	Medium	1N Ammonium acetate	Jackson (1973)
pH (1:2.5 soil: water suspension	6.54	Slightly acidic	Glass electrode digital pH meter	Jackson (1973)
EC (1:2.0 soil: water suspension) dS/m at 25^{0}C	0.30	Normal	Systronics electrical conductivity meter	Jackson (1973)

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

The crop sequences followed in the experimental field during the past five years have been presented in the Table 3.4

Table 3.4: Cropping history of experimental field

Years	*Kharif*	*Rabi*
2013-2014	Fallow	Mustard
2014-2015	Sesame	Fallow
2015-2016	Mungbean	Fallow
2016-2017	Sesame	Mustard
2017-2018	Pearl millet	Fallow
2018-2019	Mungbean	

* Experimental crop

3.5 EXPERIMENTAL DETAILS

The field experiment was laid out during *Kharif* season of 2018 in a 9 years old custard apple orchard which was planted at a spacing of 5 × 5 meter. Mungbean was sown as intercrop . The experimental trial conducted in simple randomized block design with a three replication. Each replication divided in to ten equal size plots to accommodate the treatments. Total number of plots where 30, the details of the layout of experimental field are given in the (Table 3.5)

Table 3.5: Details of treatments and their symbol used

S No.	Treatment	Treatment details
1	**T_1**	20-40-40 kg NPK (through inorganic fertilizer)
2	**T_2**	RDF + 4t/ha FYM
3	**T_3**	RDF + 3t/ha FYM
4	**T_4**	RDF + 4t/ha FYM + *Rhizobium* seed treatment
5	**T_5**	RDF + 4t/ha FYM + *Rhizobium* seed treatment + PSB
6	**T_6**	RDF + 3t/ha FYM + *Rhizobium* seed treatment
7	**T_7**	RDF + 3t/ha FYM + *Rhizobium* seed treatment + PSB
8	**T_8**	RDF + 2t/ha FYM + *Rhizobium* seed treatment
9	**T_9**	RDF + 2t/ha FYM + *Rhizobium* seed treatment + PSB
10	**T_{10}**	Control (no fertilizer /FYM application)

3.6 LAYOUT PLAN

Table 3.6 Details of layout plan

Experimental design	Randomized complete block design
No. of treatments	10
No. of replications	3
Total no. of plots	10 X 3 =30
Block border	1.0 m
Plot border	0.5 m
Gross plot size	3 m X 3 m = 9 m^2
Net plot size	2.0 m X 2.4 m= 4.8 m^2
Row to row distance	30 cm
Plant to plant distance	10 cm

3.7 AGRONOMICAL PRACTICES

The details of cultural operations done from field preparations to harvesting of the crop is given in table 3.7 below

3.7.1 Land preparation

The field was ploughed with the help of disc plough and harrowing was done followed by planking. Dry unwanted plants and remaining plant parts where removed. The field was again ploughed by cultivator and finally levelling with plank for obtaining a good tilth. Thereafter, the experiment was laid out as per plan and design.

3.7.2 FYM application

Well decomposed Farm Yard Manure (FYM) was applied before sowing and incorporated well in the soil. The quantity of FYM was calculated for respective plots according to treatments and applied accept control.

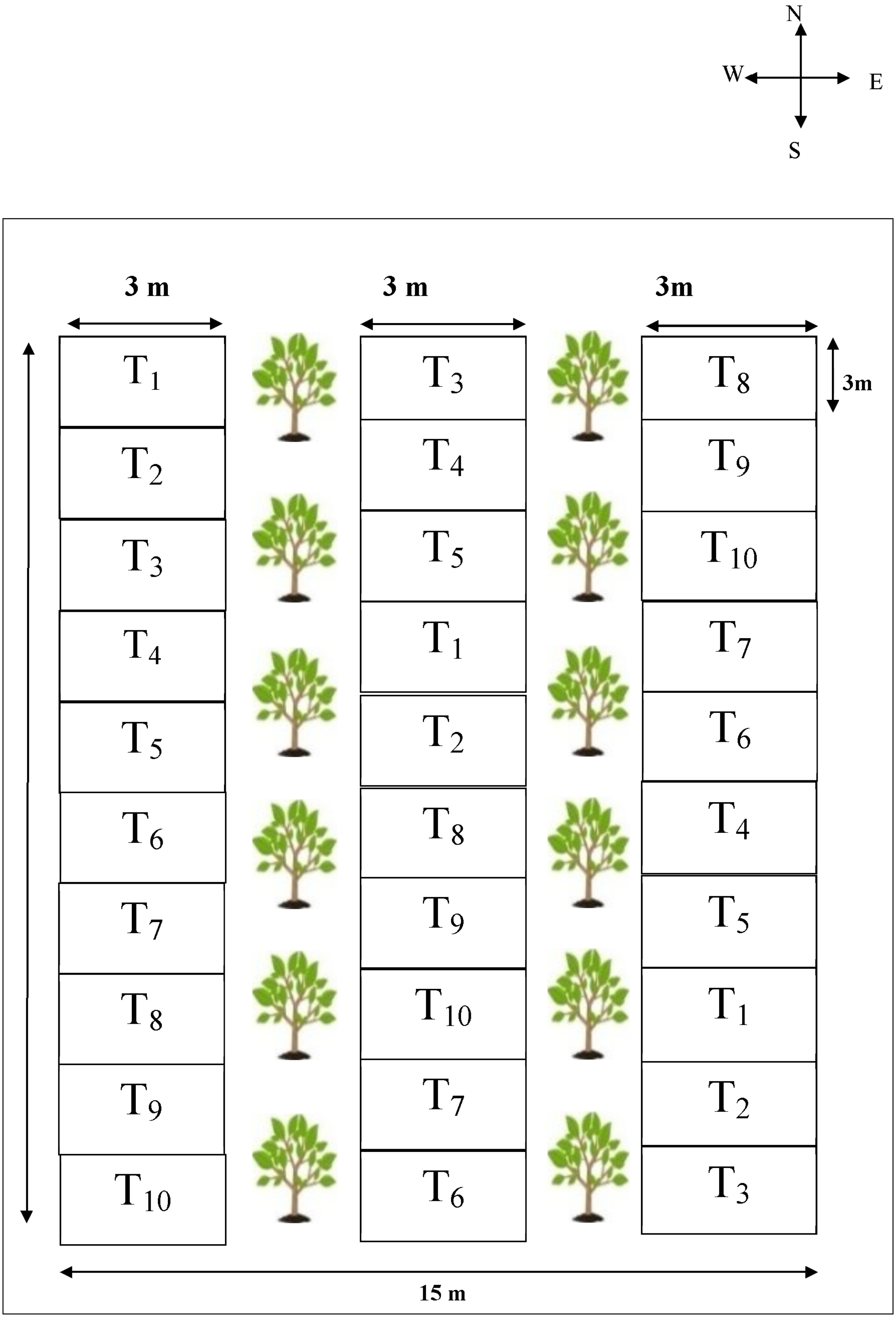

Fig. 3.2 Layout plan of the experiment

Table 3.7: Schedule operations

S. No.	Cultural operations	Date of cultural operations
A.	Pre-sowing operations	
1.	Land preparation	
	(1) First ploughing	28.07.2018
	(2) Second ploughing	30.07.2018
2.	Layout	01.08.2018
3.	Application of FYM	02.08.2018
B.	Sowing operations	
1.	Fertilizer application and sowing	13.08.2018
C.	Post sowing operations	
1.	Thinning of crop	25.08.2018
2.	Weeding and hoeing	01.09.2018
3.	Harvesting	
i)	First picking of pod	3.10.2018
ii)	Second picking of pod	14.10.2018
5.	Threshing	25.10.2018
6.	Cleaning	11.11.2018

3.7.3 Fertilizer application

Entire quantity of nitrogen, phosphorus and potash applied as per basal dose in the form of urea (46% N), diammonium phosphate (18% N and 46% P_2O_5) and murate of potash (60% K_2O) respectively each plot separately and applied just before sowing in furrow opened by spade below near about 5 cm deep.

3.7.4 Seed inoculation

Water was boiled in two 500 ml beakers and to each beaker 60 g molasses were added and dissolved and then cooled. In one beaker *Rhizobium* inoculant was mixed and in another beaker phosphate solubilizing bacteria inoculant was mixed to obtain their slurries. On the turpaline sheets the seeds were heaped and treated with

Rhizobium and phosphate solubilizing bacteria (PSB). The inoculated seeds were uniformly spreaded and dried under shade and sown immediately after drying.

3.7.5 Seed rate and sowing

The seeds of variety "HUM-16" were sown manually in the rows by *kudal* at a row distance of 30 cm as per treatment. A seed rate of 17.5 kg/ha was recommended for this variety relatively higher seed rate of 20 kg/ha was used for proper maintenance of plant population. A plant spacing of 10 cm within the row was maintained by thinning operation done about 15 days after sowing.

Variety - Malaviya Jankalyani (HUM-16)

It is a short duration variety developed by Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and notified by Central Varietal Release Committee, ICAR, New Delhi for its cultivation to entire UP. A recommended variety for cultivation in summer and *Kharif,* matures in 55-60 days. Plant height is about 45.55 cm and growth habit is erect. Pod shape is long slender, medium in size with pod length 7.5 cm and number of seeds/pod are about 11-12. The 1000-grains weight is 33-36 g and the grains are green and medium bold. Yield potential is 987 kg/ ha.

3.7.7 Thinning and intercultural operations

Extra plants were thinned at 15 days after sowing to maintain the desired plant population. One weeding was done by Khurpi manually at 18 days after sowing to control weeds.

3.7.8 Harvesting and threshing

Crop was harvested at complete maturity as judged by visual observations. The border rows were harvested first and kept aside. Thereafter, the net plots were harvested by hand picking of the pods when nearly 80 per cent pods were matured and harvested crop was left in the field for drying for a period of 3-4 days. Thereafter, small bundles were made and taken to the threshing floor. Bundle weight (grain and straw) was recorded before threshing which was done by beating the plant material with stick.

3.8 BIOMETRIC OBERSERVATIONS

Five plants from each plot were randomly selected and tagged for recording the biometric observations at different growth stages. The observations on the growth attributes were recorded at 20th, 40th days after sowing and at harvest.

3.8.1 Growth attributes

3.8.1.1 Plant height (cm)

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

3.8.1.2 Number of primary branches plant^{-1}

Branches originated from the main stem with having at least two fully developed trifoliate leaves were considered for recording for number of primary branches plant^{-1}.

3.8.1.3 Number of secondary branches plant^{-1}

Branches which are originated from primary branches with having at least two fully developed trifoliate leaves were considered for recording for number of secondary branches plant^{-1}. The numbers of secondary branches of five randomly representative plants in the penultimate rows of each plot were counted and average numbers of secondary branches plant^{-1} were worked out.

3.8.1.4 Number of root nodules plant^{-1}

Five plants from each plot were randomly uprooted along with soil from the penultimate rows with the help of khurpi. Nodules were removed from the roots with a blade were then counted, and expressed as number of nodules plant^{-1}.

3.8.1.5 Dry matter accumulation plant^{-1}

To determine the effect of different treatments on dry matter accumulation of crop, five plants were randomly uprooted from border rows of each plot at 20 days, 40 days after sowing and at harvesting stage. After removing the root portion, the above ground parts of each plot were first sun dried in envelope paper for some days and then in an oven at 70°C for 24 hours, after complete drying, the material was weighted on balance and the weight was recorded. The average was used as dry matter g plant^{-1}.

3.8.2 Yield and yield attributing characters

The following observations on yield attributes and yield studies were recorded during the experimentation.

3.8.2.1 Number of pods plant^{-1}

Total number of pods on the tagged plants were counted and average number of pods plant^{-1} were recorded.

3.8.2.2 Pod length (cm)

Length of five randomly selected pods was measured from five tagged plants and average was worked out to get the pod length.

3.8.2.3 Number of seeds pod^{-1}

The ten randomly selected pods from each five tagged plants per plot were taken out and total number of seeds were counted. Average number of seeds pod^{-1} was then calculated and recorded.

3.8.2.4 1000-seeds weight (g) / Test weight

From each plot, randomly selected 1000-seed crop yield samples were counted and their combined weight was recorded to get the test weight.

3.8.2.5 Seed yield (kg ha^{-1})

The seed yield obtained from net plot was thoroughly cleaned, sun dried and weighed treatment wise. The net plot yield was then converted and expressed as kg ha^{-1}.

3.8.2.6 Straw yield (kg ha^{-1})

The straw yield was calculated by subtracting the seed yield from biological yield (kg ha^{-1}). Straw yield of each net plot was sun-dried and then weighed treatment wisely and expressed.

3.8.2.7 Biological yield (kg ha^{-1})

Product pods and straw of each plot were recorded separately or individually after complete sun drying. With the help of the spring balance, the net plot was weighted and weight recorded in kg plot^{-1}.

3.8.2.8 Harvest index (%)

The harvest index was calculated by dividing the economic yield by biological yield and multiplying it by 100.

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

3.9 CHEMICAL ANALYSIS

3.9.1 N, P and K content (%) Plant and grain analyses

Plant material for this study was drawn at harvest of mungbean and the grain and straw were dried at 70°C for 48 hours, the plant material thus obtained was grinded with the help of grinder and passed through mesh sieve and then used for determination of N, P and K contents. The nutrient content of material was then estimated as per the following method give in (Table 3.9).

Table 3.8: Methods of plant chemical analyses

Nutrient	Analytical Method	References
Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
Phosphorus	Vanado-molybdophosphoric acid yellow colour	Jackson (1973)
Potassium	Neutral normal ammonium acetate method	Jackson (1973)

3.10 QUALITY PARAMETERS AND NUTRIENT UPTAKE

3.10.1 Protein content in seed (%)

Protein content in seed was calculated by multiplying the nitrogen percentage with 6.25 (A.O.A.C., 1960).

3.10.2 Nutrient uptake

At harvest, the plant and seed samples were collected from each plot of 3 replications for the chemical estimation. The samples were dried in an oven and then ground thoroughly with grinder and preserved in sealed and labelled containers separately for chemical analyses by following

Nutrient uptake (kg ha^{-1}) = Nutrient content (%) × Yield (kg ha^{-1})/100

3.10.2.1 Nitrogen content in seed and straw

The 0.5 g oven dried plant sample digested and nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956). The percentage nitrogen was multiplied with seed and straw yield in kg^{-1} ha to obtained N–uptake in kg ha^{-1}.

3.10.2.2 Phosphorus content in seed and straw

The phosphorus content in the digested plant samples was determined by Vanado-molybdophosphoric acid yellow colour, using spectrophotometer at 420 nm wave length (Jackson, 1973). The percentage phosphorus was multiplied with seed and straw yield (kg ha^{-1}) to obtained phosphorus uptake in kg ha^{-1}.

3.10.2.3 Potassium content in seed and straw

The potassium content in the digested samples was determined by flame photometer after making proper dilutions (Jackson, 1973). The percentage phosphorus was multiplied with seed and straw yield (kg ha^{-1}) to obtained potassium uptake in kg ha^{-1}.

OBSERVATIONS ON CUSTARD APPLE (FRUIT TREE)

It is erect, with a rounded or spreading crown and stem 10 to 15 cm thick. Height ranges from 3.5 to 5.5 m. The leaves are deciduous, alternate, oblong, 10 to 20 cm long, 2 to 5 cm wide, with conspicuous veins. Flowers, in drooping clusters, are fragrant, slender, with 3 outer fleshy, narrow petals 2 to 3 cm long; light-green externally and pale-yellow with a dark-red or purple spot on the inside at the base. The custard apple is best suited to low-lying, deep, rich soil with ample moisture and good drainage.

3.11 Growth parameters of custard apple

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

3.11.1 Height

The height of custard apple was measured from base of the plants up to growing tip of main stem. The plant height was measured and expressed in meter.

Height (m)		
At sowing	**40 DAS**	**At harvest**
4.72	**4.94**	**4.94**

3.11.2 Canopy

The canopy area of custard apple was recorded with the help of meter tape and it was recorded from the highest canopy diameter in meter.

Canopy diameter (m)		
At sowing	40 DAS	At harvest
3.82	4.18	4.25

3.11.3 Stem girth

The stem girth of custard apple was recorded from base of the plants in cm which was situated at the plot of the crops.

Stem girth (cm)		
At sowing	40 DAS	At harvest
43.13	43.25	43.29

3.11.4 Yield (kg ha^{-1})

The custard apple has the advantage of cropping in late winter and spring when the genus preferred members are not in season. It is picked when it has lost all green colour and ripens without splitting so that it is readily sold in local markets. If selected green, it will not color well and will be of inferior quality. The tree is naturally a fairly heavy bearer. The average yield was noticed 3225 kg ha^{-1} in Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur.

3.12 Economics

The cost of cultivation was worked out by taking into consideration all the expenses incurred. Gross income was worked out by multiplying seed and stalk yield of the crop with their prevailing market prices. Calculations were made as per normal rates prevalent at the Research Farm, R.G.S.C. (B.H.U.), Barkachha, Mirzapur. The cost of fertilizers, manure, plant protection chemicals and seed etc. were taken as per prevailing market prices. Net return (₹ ha^{-1}) and Benefit: Cost ratio (BC ratio) were calculated with the help of the following formula.

$$\text{Net return (₹ ha}^{-1}) = \text{Gross return (₹ ha}^{-1}) - \text{Cost of cultivation (₹ ha}^{-1})$$

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

3.13 STATISTICAL ANALYSIS

For determining the significance between the treatment means and to draw valid conclusion, statistical analysis was made. Data obtained from various observations were subjected to statistical analysis by adopting appropriate method of "Analysis of Variance". The significance of the treatment effect was judged with the help of 'F' test (Variance ratio). The difference of the treatments mean was tested using critical difference (C. D.) 5 percent probability level (Gomez and Gomez, 1976). If the variance ratio (F test) was found significant at 5% level of significance, the standard error of mean (SEm.±) and critical differences (CD) were calculated for further comparison.

$$SEm.\pm = \sqrt{\frac{Error\,sum\,of\,square}{n}}$$

Where, n = number of observations

C.D. at 5% = S.Em.± × $\sqrt{2}$ × t value at 5% of error (a) degree of freedom.

ANOVA TABLE -

Source of variance	**D.F.**	**S.S.**	**M.S.S.**	**F Value calculated**	**F Value table**	
					5%	**1%**
RSS						
TSS						
ERROR						
TOTAL						

Chapter IV

EXPERIMENTAL FINDINGS

This investigation entitled **"Effect of nutrient management through FYM and bio-inoculants in mungbean (*Vigna radiata* (L) Wilczek) under custard apple (*Annona squamosa* L.) based Agri-horti system"** was conducted during *kharif* season of 2018-19 at the Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur (U.P.). The data pertaining to various growth parameters, yield attributes, yield, nutrient content and nutrient uptake were statistically analysed and the results, thus obtained has been presented in this chapter through tables. After evaluating the data for their test of significance, observed results have been described. The experiment are presented under following heading.

4.1 GROWTH ATTRIBUTES

4.2 YIELD ATTRIBUTES

4.3 YIELD

4.4 QUALITY PARAMETERS

4.5 NUTRIENT CONTENT (%) AND THEIR UPTAKE

4.6 ECONOMICS

4.1 GROWTH ATTRIBUTES

4.1.1 Plant height (cm)

Plant height as affected by different treatments, recorded at 20, 40 days after sowing and at harvest are presented in Table 4.1.The data revealed that a rapid increase in plant height was noted during early stages of growth up to 40 DAS and successive elongation was slower. Analysis of data clearly indicated that the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly maximum plant height at 20, 40 DAS. However, it remained at par with the treatment T_2 (RDF + 4t FYM ha^{-1}), T_3 (RDF + 3t FYM ha^{-1}), T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_6 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture), T_8 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture) at 40 DAS.

At harvest treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) was observed significantly superior but it remained at par with the treatment T_3, T_4, T_6, T_7, T_8 and T_9. The minimum plant height was recorded in control treatment at all stages of crop growth.

Table 4.1: Effect of nutrient management through FYM and bio-inoculants on plant height (cm) of mungbean under custard apple based Agri-horti system.

Treatment	Plant height (cm)		
	20 DAS	**40 DAS**	**At harvest**
T_1 20-40-40 kg NPK (through inorganic fertilizer)	21.56	39.93	42.67
T_2 RDF + 4t/ha FYM	23.11	40.98	43.73
T_3 RDF + 3t/ha FYM	22.49	40.34	43.06
T_4 RDF + 4t/ha FYM + Rh	24.17	42.08	44.50
T_5 RDF + 4t/ha FYM + Rh + PSB	27.27	44.11	47.09
T_6 RDF + 3t/ha FYM + Rh	23.89	41.73	44.45
T_7 RDF + 3t/ha FYM + Rh + PSB	25.44	43.32	46.08
T_8 RDF + 2t/ha FYM + Rh	23.22	41.23	44.20
T_9 RDF + 2t/ha FYM + Rh + PSB	24.35	42.61	45.64
T_{10} Control	20.68	36.15	40.23
SEm±	0.55	1.35	1.09
CD(0.05)	1.63	4.00	3.22

RDF* - Recommended dose of fertilizer, Rh* - *Rhizobium* seed treatment
PSB* - Phosphorus solubilizing Bacteria

4.1.2 Primary branches plant^{-1} (No.)

The data relating to number of primary branches plant^{-1} at 40 DAS and at harvest as influenced by different nutrient management treatments were statistically analysed and given in Table 4.2.

The minimum number of primary branches plant^{-1} was recorded under control treatment at both stages of crop. Further analysis of data clearly indicated that the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly maximum number of primary branches plant^{-1}. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) at 40 DAS and at harvest.

Table 4.2: Effect of nutrient management through FYM and bio-inoculants on number of primary branches plant^{-1} of mungbean under custard apple based Agri-horti system.

Treatment	Primary branches plant^{-1} (No.)	
	40 DAS	At harvest
T_1 20-40-40 kg NPK (through inorganic fertilizer)	6.00	11.23
T_2 RDF + 4t/ha FYM	6.98	11.60
T_3 RDF + 3t/ha FYM	6.11	11.56
T_4 RDF + 4t/ha FYM + Rh	7.56	13.11
T_5 RDF + 4t/ha FYM + Rh + PSB	11.11	15.89
T_6 RDF + 3t/ha FYM + Rh	7.33	12.33
T_7 RDF + 3t/ha FYM + Rh + PSB	10.78	15.56
T_8 RDF + 2t/ha FYM + Rh	7.11	11.96
T_9 RDF + 2t/ha FYM + Rh + PSB	8.78	14.00
T_{10} Control	5.77	10.04
SEm±	0.36	0.55
CD(0.05)	1.07	1.62

RDF* - Recommended dose of fertilizer, Rh* - *Rhizobium* seed treatment
PSB* - Phosphorus solubilizing Bacteria

4.1.3 Secondary branches plant^{-1} (No.)

Data on the number of secondary branches plant^{-1} at 40 DAS and at harvest as influenced by different nutrient management treatments are presented in Table 4.3.

Among the various treatment, treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded maximum number of secondary branches plant^{-1}. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture) at 40 DAS.

At harvest stage, Treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) was recorded maximum number of secondary branches plant^{-1} but it remained at par with the treatment T_2 (RDF + 4t FYM ha^{-1}), T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_6 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture), T_8 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB). The minimum number of secondary branches plant^{-1} was recorded under control condition at all the observations.

Table 4.3: Effect of nutrient management through FYM and bio-inoculants on number of secondary branches plant^{-1} of mungbean under custard apple based Agri-horti system.

Treatment	Secondary branches plant^{-1} (No.)	
	40 DAS	**At harvest**
T_1 20-40-40 kg NPK (through inorganic fertilizer)	2.33	5.87
T_2 RDF + 4t/ha FYM	3.22	6.18
T_3 RDF + 3t/ha FYM	2.89	5.95
T_4 RDF + 4t/ha FYM + Rh	3.79	7.06
T_5 RDF + 4t/ha FYM + Rh + PSB	5.11	7.29
T_6 RDF + 3t/ha FYM + Rh	3.56	6.46
T_7 RDF + 3t/ha FYM + Rh + PSB	4.67	7.22
T_8 RDF + 2t/ha FYM + Rh	3.33	6.38
T_9 RDF + 2t/ha FYM + Rh + PSB	3.89	7.17
T_{10} Control	1.56	5.30
SEm±	0.19	0.41
CD(0.05)	0.55	1.20

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.1.4 Root nodules plant^{-1} (No.)

The data related to number of root nodules (plant^{-1}) at 40 DAS as influenced by different nutrient management treatments were statistically analysed and presented in Table 4.4.

The data indicated that different nutrient management significantly increased the number of root nodules plant^{-1} at peak flowering stage of mungbean over control. The maximum number of root nodules plant^{-1} at peak flowering stage were recorded under the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) which was significantly superior over control and all other treatment.

Table 4.4: Effect of nutrient management through FYM and bio-inoculants on number of root nodules plant^{-1} of mungbean under custard apple based Agri-horti system.

Treatment	Root nodules plant^{-1} (No.)
	40 DAS
T_1 20-40-40 kg NPK (through inorganic fertilizer)	11.44
T_2 RDF + 4t/ha FYM	13.33
T_3 RDF + 3t/ha FYM	12.22
T_4 RDF + 4t/ha FYM + Rh	15.33
T_5 RDF + 4t/ha FYM + Rh + PSB	21.33
T_6 RDF + 3t/ha FYM + Rh	14.66
T_7 RDF + 3t/ha FYM + Rh + PSB	18.00
T_8 RDF + 2t/ha FYM + Rh	14.00
T_9 RDF + 2t/ha FYM + Rh + PSB	16.88
T_{10} Control	9.88
SEm±	0.66
CD(0.05)	1.95

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.1.5 Dry matter accumulation plant^{-1} (g)

The data related to dry matter accumulation plant^{-1} (g) at 20, 40 and at harvest as influenced by different nutrient management treatments were statically analysed and presented in the Tables 4.5.

Table 4.5: Effect of nutrient management through FYM and bio-inoculants on dry matter accumulation plant^{-1} of mungbean under custard apple based Agri-horti system.

Treatment	Dry matter accumulation plant^{-1} (g)		
	20 DAS	40 DAS	At harvest
T_1 20-40-40 kg NPK (through inorganic fertilizer)	1.40	5.77	6.73
T_2 RDF + 4t/ha FYM	1.83	6.18	7.18
T_3 RDF + 3t/ha FYM	1.81	5.95	7.14
T_4 RDF + 4t/ha FYM + Rh	2.13	6.49	7.47
T_5 RDF + 4t/ha FYM + Rh + PSB	2.56	6.87	8.18
T_6 RDF + 3t/ha FYM + Rh	2.06	6.41	7.40
T_7 RDF + 3t/ha FYM + Rh + PSB	2.38	6.69	7.94
T_8 RDF + 2t/ha FYM + Rh	2.01	6.38	7.34
T_9 RDF + 2t/ha FYM + Rh + PSB	2.22	6.58	7.56
T_{10} Control	1.14	5.15	5.64
SEm±	0.11	0.27	0.28
CD(0.05)	0.32	0.80	0.84

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

It is clear from the data that dry matter accumulation was significantly influenced by different nutrient management treatments at 20, 40 DAS and harvest stage. The minimum dry matter accumulation was observed under control condition at all the stages of the observation. The application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded maximum dry matter accumulation which was significantly superior to control at all other treatment. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) at 20 DAS.

At 40 DAS treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly maximum dry matter accumulation but it remained at par with the treatment T_2 (RDF + 4t FYM ha^{-1}), T_3 (RDF + 3t FYM ha^{-1}), T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_6 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB), T_8 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

Treatment T_5 significantly superior at harvest but it remained at par with the T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_6 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

4.2 YIELD ATTRIBUTES

Data pertaining to yield attributes viz. number of pods $plant^{-1}$, pod length (cm), number of grains pod^{-1} and Test weight (g) as influenced by different nutrient management treatments with RDF, FYM, *Rhizobium* and PSB inoculation of the seed were presented in Table 4.6.

4.2.1 Pods $plant^{-1}$ (No.)

Data on the number of pods $plant^{-1}$ as influenced by different nutrient managements are presented in Table 4.6.

An appraisal of data presented in Table 4.6 showed that significantly maximum number of pods per $plant^{-1}$ was recorded under the treatment T_5 (RDF+ 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) which was significantly superior to control. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture). The minimum number of pods $plant^{-1}$ was recorded under control treatment.

Table 4.6: Effect of nutrient management through FYM and bio-inoculants on Yield attributes of mungbean under custard apple based Agri-horti system.

Treatment	Yield			
	Pods plant^{-1}	**Pod length (cm)**	**Grain pod^{-1}**	**Test weight (g)**
T_1 20-40-40 kg NPK (through inorganic fertilizer)	12.09	7.67	5.56	40.68
T_2 RDF + 4t/ha FYM	13.00	8.09	6.56	44.79
T_3 RDF + 3t/ha FYM	12.47	7.92	6.33	44.34
T_4 RDF + 4t/ha FYM + Rh	16.78	8.54	8.33	46.76
T_5 RDF + 4t/ha FYM + Rh + PSB	20.61	9.33	11.00	50.42
T_6 RDF + 3t/ha FYM + Rh	15.72	8.35	7.67	45.95
T_7 RDF + 3t/ha FYM + Rh + PSB	19.14	9.07	10.33	49.05
T_8 RDF + 2t/ha FYM + Rh	14.44	8.28	7.33	45.52
T_9 RDF + 2t/ha FYM + Rh + PSB	18.78	8.71	9.11	47.70
T_{10} Control	10.87	6.38	4.81	37.67
SEm±	0.81	0.49	0.49	1.43
CD(0.05)	2.40	1.46	1.45	4.25

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.2.2 Length of pods (cm)

The data on variation in pod length as influenced by different nutrient managements are presented in Table 4.6.

The minimum pod length was recorded under control treatment. Application of treatment T_5 (RDF+ 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) was recorded significantly maximum pod length but it remained at par with the treatment T_2 (RDF + 4t FYM ha^{-1}), T_3 (RDF + 3t FYM ha^{-1}), T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_6 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture), T_8 (RDF + 2t FYM ha^{-1} +

Rhizobium seed treatment) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture).

4.2.3 Grains pod^{-1} (no.)

The data recorded on number of grains per pod as influenced by different nutrient management treatments was statistically analysed in Table 4.6.

The perusal of data presented in Table 4.6 clearly indicates that the number of grains pod^{-1} was significantly affected by different nutrient management treatments. Application of treatment T_5 (RDF+ 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) was observed maximum number of grains pod^{-1} which was significantly superior over the control. However it remained at par with the treatment T_7 and T_9.

The minimum number of grains pod^{-1} was recorded under the control treatment.

4.2.3 Test weight (g)

The data pertaining to test weight (g) as influenced by different nutrient management treatments was statistically analysed and presented in Table 4.6.

The perusal of data in table 4.6 clearly reveals that test weight (g) was significantly affected by different nutrient management treatments. The significantly maximum test weight was recorded by the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB). However it remained at par with the treatment T_4, T_7 and T_9.

The minimum test weight was recorded under the control treatment.

4.3 YIELD

The mean data on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) as influenced by different nutrient management treatments have been presented in Table 4.7.

4.3.1 Grain yield (kg ha^{-1})

The data regarding grain yield (kg ha^{-1}) as influenced by different nutrient management treatments are given in Table 4.7.

A perusal of data presented in Table 4.7 indicated that the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly the higher grain yield, but it remained at par with the treatment T_4 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment), T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB culture). However the lowest grain yield was recorded under the control treatment.

4.3.2 Straw yield (kg ha^{-1})

The data pertaining to the straw yield (kg ha^{-1}) of mungbean crop influenced by different nutrient management treatments are furnished in Table 4.7.

An appraisal of data presented in Table 4.7 showed that the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly the higher straw yield in mungbean crop. However it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB). Whereas the lowest straw yield was recoded under the control.

4.3.3 Biological yield (kg ha^{-1})

An appraisal of data in Table 4.7 revealed that biological yield (kg ha^{-1}) of mungbean crop affected significantly by different nutrient management treatments.

The minimum biological yield was observed under the control treatment. While the significantly maximum biological yield was recorded under the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) but it remained at par with the treatment T_7.

Table 4.7: Effect of nutrient management through FYM and bio-inoculants on grain, straw yield (kg ha^{-1}), biological yield and harvest index (%) of mungbean under custard apple based Agri-horti system.

Treatment	Yield Kg $ha.^{-1}$		Biological yield	Harvest index
	Grain	Straw		
T_1 20-40-40 kg NPK (through inorganic fertilizer)	613.89	1416.79	2030.68	30.17
T_2 RDF + 4t/ha FYM	702.56	1544.12	2246.68	31.27
T_3 RDF + 3t/ha FYM	674.97	1482.52	2157.49	31.28
T_4 RDF + 4t/ha FYM + Rh	757.34	1730.95	2488.29	30.43
T_5 RDF + 4t/ha FYM + Rh + PSB	860.08	2081.50	2941.58	29.15
T_6 RDF + 3t/ha FYM + Rh	730.85	1649.90	2380.75	30.71
T_7 RDF + 3t/ha FYM + Rh + PSB	804.30	1862.93	2667.23	30.45
T_8 RDF + 2t/ha FYM + Rh	712.15	1595.74	2307.89	30.86
T_9 RDF + 2t/ha FYM + Rh + PSB	784.97	1786.33	2571.30	30.80
T_{10} Control	415.86	1297.96	1713.82	24.27
SEm±	36.79	81.19	95.89	1.19
CD(0.05)	109.28	241.19	284.87	3.54

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.3.4 Harvest index (%)

The data on harvest index as influenced by different nutrient management treatments are given in Table 4.7.

The minimum harvest index was recorded under the control treatment. However, the application of treatment T_3 (RDF + 3t FYM ha^{-1}), was observed significantly maximum harvest index but it remained at par with the treatment T_1, T_2, T_4, T_5, T_6, T_7, T_8 and T_9.

4.4 QUALITY PARAMETERS

4.4.1 Protein content (%) in grain

It is observed from the Table 4.8 that the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly the highest protein content. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB). While the lowest protein content was recorded under the control treatment.

Table 4.8: Effect of nutrient management through FYM and bio-inoculants on protein content in grains of mungbean, under custard apple based Agri-horti system.

Treatment	Protein content in grain (%)
T_1 20-40-40 kg NPK (through inorganic fertilizer)	12.35
T_2 RDF + 4t/ha FYM	15.08
T_3 RDF + 3t/ha FYM	14.69
T_4 RDF + 4t/ha FYM + Rh	15.44
T_5 RDF + 4t/ha FYM + Rh + PSB	17.69
T_6 RDF + 3t/ha FYM + Rh	15.33
T_7 RDF + 3t/ha FYM + Rh + PSB	16.25
T_8 RDF + 2t/ha FYM + Rh	15.19
T_9 RDF + 2t/ha FYM + Rh + PSB	15.83
T_{10} Control	10.67
SEm±	0.63
CD(0.05)	1.87

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.5 NUTRIENT CONTENT (%) AND THEIR UPTAKE (kg ha^{-1})

Analysis of nutrient contents in grain and straw sample and their uptake as affected by different fertility levels with FYM and seed inoculation by bio-inoculants (*Rhizobium* and PSB).

4.5.1 Nitrogen content in grain and straw (%)

A perusal of data presented in Table 4.9 showed that the nitrogen content in grain and straw. The application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly higher nitrogen content in grain and straw. But it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) and T_9 (RDF + 2t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) and lowest nitrogen content in grain and straw was recorded under control.

Table 4.9: Effect of nutrient management through FYM and bio-inoculants on nitrogen content (%) and nitrogen uptake (kg ha^{-1}) at harvest of mungbean under custard apple based Agri-horti system.

Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		Total (grain + straw) N uptake
	Grain	Straw	Grain	Straw	
T_1 20-40-40 kg NPK (through inorganic fertilizer)	1.98	1.06	12.34	15.05	27.39
T_2 RDF + 4t/ha FYM	2.41	1.11	16.97	17.16	34.13
T_3 RDF + 3t/ha FYM	2.35	1.10	15.90	16.30	32.20
T_4 RDF + 4t/ha FYM + Rh	2.47	1.18	18.67	20.40	39.07
T_5 RDF + 4t/ha FYM + Rh + PSB	2.83	1.27	24.40	26.42	50.82
T_6 RDF + 3t/ha FYM + Rh	2.45	1.17	17.91	19.32	37.24
T_7 RDF + 3t/ha FYM + Rh + PSB	2.60	1.22	20.88	22.70	43.58
T_8 RDF + 2t/ha FYM + Rh	2.43	1.15	17.35	18.40	35.74
T_9 RDF + 2t/ha FYM + Rh + PSB	2.53	1.20	19.84	21.52	41.36
T_{10} Control	1.71	0.86	7.13	11.21	18.34
SEm±	0.11	0.04	1.31	1.32	2.26
CD(0.05)	0.32	0.12	3.88	3.92	6.72

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.5.2 Uptake of nitrogen by grain and straw (kg ha^{-1})

The data furnished in Table 4.9 indicated that treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly higher nitrogen uptake by grain and straw. However, it remained at par with the treatment T_7 (RDF + 3t FYM ha^{-1} + *Rhizobium* seed treatment + PSB), while the lowest nitrogen uptake by grain and straw was recorded under the control.

4.5.3 Phosphorus content in grain and straw (%)

The data pertaining to phosphorus content in grain and straw of mungbean as affected by different nutrient management treatments presented in Table 4.10.

The phosphorus content in grain and straw was significantly affected due to different nutrient management treatments. Significantly the maximum phosphorus content in grain and straw was registered in the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB), which was significantly superior. While the minimum phosphorus content in grain and straw under the control treatment.

4.5.4 Uptake of Phosphorus by grain and straw (kg ha^{-1})

The data presented on phosphorus uptake by grain and straw are presented in Table 4.10.

The lowest phosphorus uptake by grain and straw under the control treatment. While the significantly higher Phosphorus uptake by grain and straw recorded under the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

4.5.4 Uptake of Phosphorus by grain and straw (kg ha^{-1})

The data presented on phosphorus uptake by grain and straw are presented in Table 4.10.

The lowest phosphorus uptake by grain and straw under the control treatment. While the significantly higher Phosphorus uptake by grain and straw recorded under

the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

Table 4.10: Effect of nutrient management through FYM and bio-inoculants on phosphorus content (%) and phosphorus uptake (kg ha^{-1}) at harvest of mungbean under custard apple based Agri-horti system.

Treatment	Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		Total (grain + straw) P uptake
	Grain	Straw	Grain	Straw	
T_1 20-40-40 kg NPK (through inorganic fertilizer)	0.29	0.10	1.80	1.46	3.26
T_2 RDF + 4t/ha FYM	0.34	0.13	2.41	1.95	4.36
T_3 RDF + 3t/ha FYM	0.32	0.12	2.18	1.77	3.95
T_4 RDF + 4t/ha FYM + Rh	0.41	0.16	3.11	2.71	5.82
T_5 RDF + 4t/ha FYM + Rh + PSB	0.47	0.22	4.04	4.56	8.60
T_6 RDF + 3t/ha FYM + Rh	0.39	0.15	2.85	2.42	5.27
T_7 RDF + 3t/ha FYM + Rh + PSB	0.44	0.19	3.51	3.46	6.97
T_8 RDF + 2t/ha FYM + Rh	0.38	0.14	2.73	2.23	4.96
T_9 RDF + 2t/ha FYM + Rh + PSB	0.43	0.17	3.35	3.10	6.45
T_{10} Control	0.24	0.08	1.01	0.99	2.00
SEm±	0.01	0.01	0.15	0.12	0.17
CD(0.05)	0.02	0.02	0.44	0.36	0.51

RDF*- Recommended dose of fertilizer, Rh*- *Rhizobium* seed treatment
PSB*- Phosphorus solubilizing Bacteria

4.5.5 Potassium content in grain and straw (%)

The data presented in Table 4.11 showed that the potassium content in grain and straw was significantly affected by different nutrient management treatments.

Application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded significantly higher potassium content in grain and straw. While the minimum potassium content in grain and straw found under the control treatment.

4.5.6 Uptake of Potassium by grain and straw (kg ha^{-1})

The data furnished in Table 4.11 indicated that the treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB) recorded higher potassium uptake by grain and straw which was significantly superior to all other treatments. While the lowest potassium uptake recorded under control treatment.

Table 4.11: Effect of nutrient management through FYM and bio-inoculants on potassium content (%), and potassium uptake (kg ha^{-1}) at harvest of mungbean under custard apple based Agri-horti system.

Treatment	Potassium content (%)		Potassium uptake (kg ha^{-1})		Total (grain + straw) K uptake
	Grain	Straw	Grain	Straw	
T_1 20-40-40 kg NPK (through inorganic fertilizer)	1.06	2.01	6.50	28.52	35.02
T_2 RDF + 4t/ha FYM	1.12	2.26	7.87	34.84	42.71
T_3 RDF + 3t/ha FYM	1.10	2.19	7.45	32.46	39.91
T_4 RDF + 4t/ha FYM + Rh	1.20	2.38	9.11	41.20	50.31
T_5 RDF + 4t/ha FYM + Rh + PSB	1.31	2.44	11.27	50.74	62.01
T_6 RDF + 3t/ha FYM + Rh	1.18	2.35	8.60	38.72	47.32
T_7 RDF + 3t/ha FYM + Rh + PSB	1.28	2.41	10.32	44.91	55.23
T_8 RDF + 2t/ha FYM + Rh	1.17	2.30	8.35	36.73	45.08
T_9 RDF + 2t/ha FYM + Rh + PSB	1.25	2.40	9.79	42.89	52.68
T_{10} Control	1.01	1.87	4.21	24.23	28.44
SEm±	0.01	0.02	0.45	1.97	2.09
CD(0.05)	0.03	0.05	1.34	5.84	6.21

RDF* - Recommended dose of fertilizer, Rh* - *Rhizobium* seed treatment
PSB* - Phosphorus solubilizing Bacteria

4.6 ECONOMICS (Mungbean)

Research finding may highly be useful from academic point of view but would not be useful to the farmers unless these findings are economically feasible from the point of its adoption by beneficiaries.

The economic analysis includes the cost of cultivation, gross return, net return and benefit: cost for different treatment combination and the data in respect of economics have been summarized in Table 4.12.

4.6.1 Cost of cultivation (₹ ha^{-1})

The common cost of cultivation of different treatment combinations were work out, considering all operation from land preparation to harvesting and input used. The treatment cost was calculated separately and it was combined with common cost of cultivation to find out the total cost of cultivation. Data presented in table revealed that the total cost of cultivation was minimum ₹ 1490.95 ha^{-1} under the control treatment. While the total cost of cultivation was maximum ₹ 29471.83 ha^{-1} was under the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

4.6.2 Gross return (₹ ha^{-1})

It is evident from the data the among different fertility levels and inoculation of seed with *Rhizobium* seed treatment and PSB culture was recorded minimum gross return in alley cropping of ₹ 31602.15 ha^{-1} under the control. The maximum gross return of ₹ 64153.67 ha^{-1} was recorded in custard based cropping system under the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

4.6.3 Net return (₹ ha^{-1})

The net return was markedly influenced due to different cost incurred and yield (grain and straw) obtained under various treatments. The minimum net return of ₹ 10111.20 ha^{-1} was recorded under control. And the maximum net return of ₹ 34681.84 ha^{-1} was recorded under the application of treatment T_5 (RDF + 4t FYM ha^{-1} + *Rhizobium* seed treatment + PSB).

4.6.4 Benefit: cost

The data on benefit: cost indicated that the maximum Benefit: cost 2.18 was recorded due to combined inoculation of *Rhizobium* and PSB culture with RDF + 4t FYM ha^{-1}. However the minimum benefit: cost 1.47 was recorded under the control treatment.

Table 4.12: Effect of nutrient management through FYM and bio-inoculants on relative economics.

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})			Net return (₹ ha^{-1})	B:C
		Grain	Straw	Total		
T_1 20-40-40 kg NPK (through inorganic fertilizer)	25391.83	42818.83	2833.58	45652.41	20260.58	1.80
T_2 RDF + 4t/ha FYM	29391.83	49003.56	3088.247	52091.81	22699.98	1.77
T_3 RDF + 3t/ha FYM	28391.83	47079.16	2965.047	50044.2	21652.37	1.76
T_4 RDF + 4t/ha FYM + Rh	29431.83	52824.47	3461.907	56286.37	26854.54	1.91
T_5 RDF + 4t/ha FYM + Rh + PSB	29471.83	59990.68	4162.995	64153.67	34681.84	2.18
T_6 RDF + 3t/ha FYM + Rh	28431.83	50976.86	3299.793	54276.65	25844.82	1.91
T_7 RDF + 3t/ha FYM + Rh + PSB	28471.83	56100.16	3725.86	59826.02	31354.19	2.10
T_8 RDF + 2t/ha FYM + Rh	27431.83	49672.7	3191.48	52864.18	25432.35	1.93
T_9 RDF + 2t/ha FYM + Rh + PSB	27471.83	54751.66	3572.667	58324.32	30852.49	2.12
T_{10} Control	21490.95	29006.24	2595.913	31602.15	10111.2	1.47

RDF* - Recommended dose of fertilizer, Rh* - *Rhizobium* seed treatment
PSB* - Phosphorus solubilizing Bacteria

4.7 ECONOMICS (Custard apple)

The economic analysis of custard apple includes the cost of cultivation, gross return, net return and benefit: cost ratio.

Total cost of cultivation of custard apple was recorded ₹ 33056.43 ha^{-1}, Gross return ₹ 129000 ha^{-1}, Net return ₹ 95943.57 ha^{-1} and B: C ratio 2.90.

DISCUSSION

The present investigation entitled **"Effect of nutrient management through FYM and bio-inoculants in mungbean [*Vigna radiata* (L.) Wilczek] under custard apple (*Annona squamosa* L.) based Agri-horti system"** was carried at the Agricultural Research Farm Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha Mirzapur, U. P. during the 2018 *kharif* season. The experimental finding has been presented in the preceding chapter in detail. In this chapter, an exertion has been made to evaluate the important observations recorded in terms of cause and effect relationship during the examination. A crop's final yield is a net result of the extent to which growth and development activities in individual plants are successfully completed, which in turn would depend on the crop's genetic potential and the environmental conditions to which it is exposed during its life cycle.

Growth and development of crop plants are directly related to their genetics, although their direct and indirect role in different metabolic processes also affects the growth and development of plants as well as environmental factors, cultural practices and alley cropping system. The finding shall be discussed after short-lived remark on the weather situation during the crop period. Weather data shows plenty of additional soil moisture at periodic intervals. The crop saw a normal weather so far as temperature, relative humidity sun-shine hour's etc., were concerned. In alley cropping system, apart from all factors fertility levels and farm yard manure and bio-inoculants combination of the respective components crop and their competitive relation are of supreme important.

Yield per unit area is the cumulative yield function per plant. Yield plant^{-1} is the function of pod plant^{-1}, number of grain pod^{-1} and test weight. There are some growth parameters that contribute indirectly to yield. These characters are affected by physiological and metabolic processes that are modified by environmental condition, application of fertilizer, and other cultural practices. The yield variation was analyzed in terms of yield component differences.

The findings of earlier workers on the subject have also been taken in to consideration were while discussing the result of present investigation. The discussion is presented under various heads.

5.1 EFFECT OF WEATHER CONDITIONS ON GROWTH AND YIELD OF MUNGBEAN

Weather conditions affected the results of field investigations. Therefore, any discussion of the results would not be appropriate without taking into account the weather relationship with the crop in order to arrive at the correct interception and conclusion.

The weather factors *viz*., rainfall, temperature, relative humidity, evaporation and sunshine hours recorded during crop duration of the present experimentation are given in Table 3.1. The variation in weather parameters has a pronounced effect on crop growth. Each crop has its own cardinal point of air temperature, relative humidity, vapor pressure, and hours of sunshine to achieve the yield potential. If the variation becomes too wide from the optimum, the plant will suffer from poor growth, development and yield. This effect is more pronounced in agricultural crops compared to trees in adverse climatic and edaphic conditions.

Each crop requires a set of definite environmental conditions for its proper growth and development. In addition to alley cropping and weather parameters such as temperature, rainfall, sun-shine duration, relative humidity and evaporation are the main factor that influenced crop growth and development. Mungbean is generally grown in northern India as a summer and rainy season crop. During the flowering stage, heavy rainfall is harmful and adversely affects production. Such crops require a hot and humid climate during growing period. Mungbean is extremely susceptible to water logging and heavy continuous rains and hail damage at all stages of growth. Temperature is known to have a strong effect on such crop's vegetative and reproductive phases.

The optimal temperature severely affects germination and plant standing. The meteorological data (Table 3.2) recorded during the crop season showed that the average temperature remained between 20.9 °C to 32.15 °C within the optimum range for a mungbean growth. The weather conditions did not cause any variable effect on the behavior of an individual treatment tested. Thus variation in the crop yields observed under investigation were mainly due to the effect of an individual treatment.

5.2 EFFECT OF TREATMENTS ON CROP

5.2.1 Effect on growth parameters

Result of experiment revealed that growth parameters of mungbean (Table 4.1 to Table 4.6) showed variation due to different FYM levels and bio-inoculation. The RDF (20:40:40 NPK), dual inoculation of *Rhizobium* and PSB along with 4 t FYM ha^{-1} recorded higher growth *viz*., plant height, number of primary and secondary branches $plant^{-1}$, dry matter accumulation and number of root nodules $plant^{-1}$ in mungbean as compared to different FYM level, dual inoculation (*Rhizobium* and PSB), un-inoculation of biofertilizers and control treatment. This might be due to the combined application of RDF, FYM, *Rhizobium* and PSB. Which increased the availability of nitrogen as a major component of chlorophyll. Which facilitated the synthesis of food materials resulting in increased cell division and cell enlargement, and Phosphorus enhances root elongation, leaf expansion, and helps in cell elongation. Potassium plays a major role in the regulation of water in plants and important for the activation of many growth-related enzymes. It has the ability to strengthen stalks and stems against diseases, protecting the plant from lodging. FYM is rich in nutrients and all the nutrients required by the plants are present. *Rhizobium* help in the fixation of atmospheric nitrogen and PSB also play an important role in mediating Phosphorus availability to plants, enhancing the capacity of plants to acquire Phosphorus from the soil.

This could have contributed to the increase in plant height with the inclusion of RDF, FYM and combined biofertilizer inoculation (*Rhizobium* and PSB). These results are in collaborated with those of Selvakumar *et al.* (2009), Amit *et al.* (2010), Koushal *et al.* (2011), Kundu *et al.* (2013), Zadode *et al.* (2013) and Patel *et al*. (2016).

The increased growth parameters may be attributed to increased cell division due to sufficient supply of nitrogen, phosphorus, potassium by inorganic fertilizers, FYM and dual inoculation of *Rhizobium* & PSB and also the genetic characters of variety. Beneficial effect of FYM in conjunction with RDF and biofertilizers may be due to the effect of organic matter in improving physical, chemical and biological environment of soil conducive to better plant growth (Deshmukh *et al.*, 2005). Vegetative growth mainly consist of the formation of new leaves, stem and nodules and these maristemic tissues have a very active protein metabolic photosynthetic transported to these sites are used predominantly in the synthesis of protein.

The number of Primary branches plant^{-1} and secondary branches plant^{-1} was significantly increased with the higher fertility levels (FYM) under dual inoculation of *Rhizobium* and PSB as compared to their un-inoculation, *Rhizobium* alone and control during all observation period. Integrated usage of RDF, FYM and dual inoculation of *Rhizobium* and PSB. These results are in Collaboration with those of Amit *et al*. (2010), Kant *et al.* (2016), Seerat un Nissa *et al.* (2017).

Number of root nodules plant^{-1} was significantly increased with the higher fertility levels (FYM) under the dual inoculation of *Rhizobium* and PSB as compared to their un-inoculation, *Rhizobium* alone and control at 40 DAS. It was due to higher number of bacteria present under inoculated condition than *Rhizobium* alone and un-inoculated plots. PSB inoculation showed more available phosphorus in soil, which favored better root growth and resulted in a beneficial effect of nodulation with increased *Rhizobium* bacterial activity. Amit *et al*. (2010), Zadode *et al.* (2013), Kant *et al.* (2016), Singh *et al.* (2018) reported similar result.

Dual inoculation of *Rhizobium* and phosphate solubilizing bacteria (PSB) may help the plant to acquire both N and P. Dual inoculation of PSB and *Rhizobium* have been found to improve the nodulation and nitrogen fixation. Interest has been focused on the inoculation of *Rhizobium* and PSB into the soil to increase the availability of native fixed phosphate and to reduce the use of fertilizers (Chakrabarti *et al.*, 2010).

Dry matter accumulation increased markedly with dual inoculation of *Rhizobium* and PSB under the higher FYM level. Such influence of treatment may be attributed to higher microbial population favoring more N contents (%) and its association with increased chlorophyll formation due to *Rhizobium* inoculation and due to PSB inoculation, increased phosphatase activity means increased phosphorus supply to plants and the beneficial effects of production of growth regulators. The results were in close conformity with the obviation recorded by Beg *et al.*, (2009), Patel *et al.*, (2013), Zadode *et al.*, (2013).

5.2.2 Effect on yield attributes and yield

In the present study, dual inoculation of *Rhizobium* and PSB with RDF and 4t FYM ha^{-1} showed significantly increased pod length, number of pods $plant^{-1}$, number of grains pod^{-1} and test weight over the control (Table 4.6 and 4.7). It was due to closeness of custard apple tree canopy resulting increased competition among components for light, moisture and nutrient. However, grain and straw yield significantly increased with increasing rate of FYM with biofertilizers (RDF + 4t FYM ha^{-1} + *Rhizobium* and PSB).

This could be due to the dual inoculation of *Rhizobium* and PSB with RDF and 4 t FYM ha^{-1} which enhanced root nodulation and faster root development and enhanced nutrient accessibility, leading in strong crop growth and dry matter accumulation. which resulted in better flowering, fruiting and pod development and eventually PSB which could have helped in reducing phosphorus fixation by its effect and also solubilized the unavailable form of phosphorus leading to more removal of nutrients by the crop which reflected in better growth parameters viz., pods $plant^{-1}$ and grains $pod^{-1.}$ The increase in grain, straw and biological yield was due to the cumulative effect of increased growth and yield parameters.

Boosted vegetative growth in terms of dry matter production of crop and number of branches $plant^{-1}$ provided more spots or places for the translocation of photosynthates and ultimately caused in increased the number of pods $plant^{-1}$, pod length, grains pod^{-1} and test weight were significantly promoted with the availability of nutrients through RDF, *Rhizobium*, PSB and FYM levels during growing season of crop which eventually contributed towards higher yield.

The number of grains pod^{-1} and test weight were also increased due to RDF, different FYM levels with dual inoculation of *Rhizobium* + PSB. The maximum pods plant^{-1}, straw yield and test weight were recorded in treatment T_5 under dual inoculation of *Rhizobium* + PSB in agri-horti system. Combination of organic and inorganic fertilizers increased the 1000-seed weight than use of inorganic fertilizer alone. This may be because organic fertilizers are known to contain plant nutrients, growth promoting substances and beneficial microflora which in combination with inorganic fertilizers provide favourable soil conditions to enhance nutrient use efficiency. Similar results were reported by A.S. Channaveerswami (2005) in groundnut and D.J. Rajkhowa *et al*. (2002) in green gram. This might be attributed to Improved nutritional status in plant parts under FYM application primarily seems to be on account of enrichment of these nutrients in soil, secondly it can be attributed to their efficient extraction per translocation in the plant system due to enhanced activities of roots on account of crucial role of FYM on maintenance of better physico-chemical and biological properties of the soils and better supply of Nitrogen, Phosphorus, potassium with the FYM and biofertilizers (*Rhizobium* + PSB) resulting in higher branch and pods and there by higher yield. It is an established fact that phosphorus plays an important role in the formation of new shoots there by increases the number of branches plant^{-1}. In addition, it controls the photosynthetic and carbohydrate metabolism which are considered to be one of the major factors limiting growth particularly during the reproductive phase.

The better growth of plant in terms of height and dry matter accumulation might have helped in improving yield parameters and yield of green gram through better translocation of food reserves to sink. The levels of phosphorus during this period regulate the starch/sucrose ratio in the source levels and the reproductive organs. It also influences the stomatal resistance and activity of ribilose bi- phosphate carboxylase. Thus, the stimulatory effect of nitrogen and phosphorus on growth and partitioning of photosynthates to sink development has led to increased number of pods plant^{-1}, grains pod^{-1} and test weight. The corresponding lower values of these parameters at lower doses further lend support to the above statement. The analyzed data on grain and straw yields revealed that application RDF, 4t FYM under dual inoculation of seed with *Rhizobium* and PSB showed significant improvement compared to single inoculation with *Rhizobium* and un-inoculation of seed.

Application of nitrogen appears to be cumulative effect of dry matter accumulation and greater removal of nitrogen during reproductive and grain filling stages. This was also due to the beneficial effect of phosphorus and potassium which brought about stimulating effect of phosphorus, potassium on plant processes, *viz*., cell division and root elongation in meristemic tissues and constitute of ADP and ATP in plant, which plays an important role in energy storage. With increased dry matter and photosynthetic products, coupled with efficient translocation, plant produced more pods plant^{-1} with more number of grains pod^{-1} and higher test weight. The significant increase in grain and straw yields appeared to be on account of the beneficial effects of nitrogen, phosphorus under dual inoculation of *Rhizobium* and PSB on growth and yield attributes which finally reflected in higher yield of green gram.

Varma *et al.* (2017) also found higher yield due to the seed inoculation with *Rhizobium* + PSB which increased higher number of pods plant^{-1}, number of grains pod^{-1}, test weight were the major parameters governing the yield. Similar finding have also been reported by Yadav (2004), Kumawat *et al.* (2010), Hussain *et al.* (2011) and Tagore *et al.* (2013).

5.2.3 Effect on nutrient contents (%) and uptake

The content and uptake of nitrogen, phosphorus and potassium in grain and straw were shown a significantly positive effect due to different inoculants enhanced (G.S. Tagore *et al.*, 2014). Undoubtly increase in nitrogen availability in soil leads to increase in content of nitrogen and phosphorus application in seed and straw (Singh

2018). The inoculation of seed with *Rhizobium* and PSB culture increased the nitrogen contents in grain as well as straw. This might be due to more nitrogen fixation by the bacteria which in turn helped in better absorption and utilization of all the plant nutrients, thus resulting in more N contents in grain and straw. This beneficial influence might be due to better root establishment by nodulation, nitrogen fixation from atmosphere. The nutrient removal is an integrated function of soil-crop environment, together with amounts and source of nutrients supply and cultivars of crop. The term uptake denotes the net movement of mineral from the ambient medium to the plant and numerically is a product of nutrient concentration and yield. The amount of the nutrients taken up by a plant depends upon intensity factor of available nutrient in the soil. When a nutrient element in short supply, its low availability is adversely affected, the growth and changes the cellular metabolism which may lead to the growth and development of visual symptoms of its deficiency.

Improved nutritional status in plant parts under FYM application primarily seems to be on account of enrichment of these nutrients in soil, secondly it can be attributed to their efficient extraction per translocation in the plant system due to enhanced activities of roots on account of pivotal role of FYM on maintenance of better physico-chemical and biological properties of the soils. Similar results were also reported by Shankar *et al.* (2014) and Kokani *et al.* (2014).

Higher nitrogen, phosphorus and potassium contents in grain and straw of mungbean were observed under the dual inoculation of seed with *Rhizobium* + PSB with RDF and 4 t FYM ha^{-1}. Reduction in FYM level, single inoculation (*Rhizobium*) or un-inoculation of seed significantly decreased its contents in plants. The control treatment showed the lowest nitrogen, phosphorus and potassium contents in grain and straw. Protein molecules are built up through systematically controlled condensation of amino acid molecules, formed by combining reduced nitrogen with derivatives of carbohydrates obtained with in the plant system as a produce of photosynthesis. The results are in close conformity with the findings of Dekhane *et al.* (2011), Chaudhary *et al.* (2016), Dhakal *et al.* (2016), Patel *et al.* (2016), Bhavya *et al.* (2018).

5.2.4 **Relative economics** (Mungbean)

The gross return of mungbean crop varied markedly by influence of various treatments which ultimately influenced the overall net income and benefit: cost ratio. The data on relative economics of various treatments (Table 4.12) revealed that the maximum net return RDF and 4t FYM ha^{-1} with dual inoculation of *Rhizobium* + PSB. However, the benefit: cost ratio was higher under dual inoculation of biofertilizers. The minimum net return and benefit: cost was recorded under control. The higher income return under RDF and 4t FYM ha^{-1} with dual inoculation of *Rhizobium* + PSB can be correlated with the increased yield in this treatment. These results are in conformity with the finding of Beg and Singh (2009) and Kumawat *et al*. (2017).

Chapter VI

SUMMARY AND CONCLUSION

In this chapter an attempt was made to summarize the results presented in the experimental findings chapter and also to appeal valid conclusions based on the significant findings of the present investigation entitled **"Effect of nurtient management through FYM and bio-inoculants in mungbean (*Vigna radiata* (L) Wilczek) under custard apple *(Annona squamosa* L.) based Agri-horti system".** The investigation was conducted during the 2017 rainy (*Kharif*) season at the Rajiv Gandhi South Campus Agricultural Research Farm, Banaras Hindu University, Barkachha, Mirzapur.

The experimental field soil was textured sandy loam with P^H 6.5. It was poorly fertile, low in available organic carbon (0.27%), available nitrogen (227.6 kg ha^{-1}), low in available phosphorus (20.55 kg ha^{-1}) and available potassium (242.36 kg ha^{-1}). The experiment was carried out in Randomized Block Design under custard apple based agri- horti system. Treatments were replicated three times. The experiment conducted ten treatments.

The required seed quantity for mungbean at a rate of 20 kg ha^{-1} was sown. The seeds were sown directly in rows 30 x 10 cm apart with the help of kudal. The experiment was conducted with thirteen-year-old custard apple trees planted at a distance of 5 x 5 m.

The response of the crops to the treatments was measured in terms of different quantitative indices, i.e., plant height, number of root nodules $plant^{-1}$, dry matter accumulation $plant^{-1}$, number of primary and secondary branches $plant^{-1}$, yield components i.e., number of pods $plant^{-1}$, pod length (cm), number of grains pod^{-1}, seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield and harvest index (%). Soil was analyzed for available nitrogen, phosphorus and potassium at initiation of the experiment. In order to draw a valid conclusion, the data collected during the experiment were subjected to statistical analysis. Finally, the different treatments were analyzed for their gross return, net return and benefit:cost. The important findings and broad conclusions emerging from the investigation are summarized as below.

1. The mungbean plant height as influenced under custard apple based Agri-horti system significantly increased at 20, 40 DAS and at harvest with inoculation of *Rhizobium* and PSB to seed under the application of RDF + 4 t FYM ha^{-1} fertility level but minimum plant height was noticed under control.
2. The maximum root nodules was recorded under combined inoculation of seed by *Rhizobium* and PSB with application of RDF + 4 t FYM ha^{-1}.
3. Dual inoculation of seed with *Rhizobium* and PSB with RDF + 4 t FYM ha^{-1} Produced significantly maximum number of primary and secondary branches plant $^{-1}$ in mungbean.
4. Maximum dry matter accumulation by mungbean was obtained dual inoculation of *Rhizobium* and PSB with RDF + 4 t FYM ha^{-1}.
5. The number of pods $plant^{-1}$ were more with the application of RDF + 4 t FYM ha^{-1} and *Rhizobium* + PSB. While, minimum was noted in control.
6. Number of grains pod^{-1} were more with the application of RDF + 4 t FYM ha^{-1} and *Rhizobium* + PSB. While, minimum was noted under control.
7. The 1000 grains weight of mungbean under custard apple based agri-horti system was significantly higher with RDF + 4 t FYM ha^{-1} and *Rhizobium* + PSB than control.
8. The dual inoculation of *Rhizobium* and PSB along with application of RDF + 4 t FYM ha^{-1} recorded significantly maximum grains and straw yield of mungbean over the control.
9. The Nitrogen, Phosphorus and Potassium contents in grain and straw of mungbean significantly improved due to dual inoculation of *Rhizobium* and PSB along with the RDF + 4 t FYM ha^{-1}. However, maximum nutrient uptake by grain, straw and total were noted under RDF + 4 t FYM ha^{-1} and *Rhizobium* + PSB.

10. The highest net return of mungbean crop Rs. 34681.84 ha^{-1} was recorded under combined inoculation of *Rhizobium* and PSB along with RDF + 4 t FYM ha^{-1} and minimum Rs. 10111.20 ha^{-1} in control condition.

11. The higher benefit: cost ratio of mungbean crop (2.18) was observed with RDF + 4 t FYM ha^{-1} and *Rhizobium* + PSB as compared to control (1.47).

CONCLUSIONS

It is concluded that mungbean variety 'HUM-16' intercropped in alleys of custard apple be fertilized with T_5 + RDF + 4 t FYM ha^{-1} along seed treatment with *Rhizobium* and phosphate solubilizing bacteria to level proved beneficial for boosting grain yield (860.08 kg ha^{-1}) and gave maximum net return (Rs.34681.84 ha^{-1}) and benefit: cost ratio (2.18) and thus it could be recommended for profitable production under the obtain higher yield of mungbean and income under *Vindhyan* region of Mirzapur.

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APPENDICES

Appendix I: Common cost of cultivation (₹ ha^{-1})

S.No.	Operations	Input	Rate (₹)	Cost (₹)
1.	Land preparation			
	(i) One deep ploughing by soil turning plough	One tractor (35 HP) for 2.5 hrs	600 Rs ha^{-1}	1500
	(ii) Harrowing and Planking	One tractor (35 HP) for 4 hrs	600 Rs ha^{-1}	2400
2.	Layout	15 labour day^{-1}	290 labour^{-1}	4,350
3.	Seeding and sowing	One tractor (35 HP) with seed drill for 2 hrs	600 Rs ha^{-1}	1200
4.	Seed (cultivar : HUM-16)	20 kg/ha	180 Rs./kg	3600
5.	Thinning and weeding (Mungbean)	13 labour^{-1}	290 labour^{-1}	3,770
6.	Harvesting and threshing	11 labour^{-1}	290 labour^{-1}	3,190
7.	Land revenue	For 6 months	150 annum^{-1}	75
8.	Working Capital			20,085
9.	Interest on working capital	For 6 months	14% annum^{-1}	1405.95
			Total	21,490.95

Appendix II: Cost of cultivation treatment wise

Treatment	Labour required (No.)	Labour cost @ 290 lab.$^{-1}$	Fertilizer doses (kg ha^{-1})			FYM Dose t ha^{-1}	Amount of bio-fertilzer (g.)		Cost of fertilizer (₹ ha^{-1})				Cost of bio-fertilizers (₹ ha^{-1})		Treatments cost (₹ ha^{-1})	Common cost (₹ ha^{-1})	Total cost (₹ ha^{-1})
			Urea	DAP	MOP		*Rh.*	PSB	Urea	DAP	MOP	FYM	*Rh*	PSB			
T_1	2	580	9.5	86	66.66				57	2064	1199.88				3,900.88	21,490.95	25,391.83
T_2	2	580	9.5	86	66.66	4			57	2064	1199.88	4000			7,900.88	21,490.95	29,391.83
T_3	2	580	9.5	86	66.66	3			57	2064	1199.88	3000			6,900.88	21,490.95	28,391.83
T_4	2	580	9.5	86	66.66	4	400		57	2064	1199.88	4000	40		7,940.88	21,490.95	29,431.83
T_5	2	580	9.5	86	66.66	4	400	400	57	2064	1199.88	4000	40	40	7,980.88	21,490.95	29,471.83
T_6	2	580	9.5	86	66.66	3	400		57	2064	1199.88	3000	40		6,940.88	21,490.95	28,431.83
T_7	2	580	9.5	86	66.66	3	400	400	57	2064	1199.88	3000	40	40	6,980.88	21,490.95	28,471.83
T_8	2	580	9.5	86	66.66	2	400		57	2064	1199.88	2000	40		5,940.88	21,490.95	27,431.83
T_9	2	580	9.5	86	66.66	2	400	400	57	2064	1199.88	2000	40	40	5,980.88	21,490.95	27,471.83
T_{10}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21,490.95	21,490.95

Appendix III: Total cost of cultivation in custard apple.

S.No.	Operation	Unit	Input	Rate (₹)	Cost (₹)
1.	NPK (400-250-800 g plant^{-1})	Urea kg ha^{-1}	262.76	6	1576.56
		DAP kg ha^{-1}	217.39	24	5217.36
		MOP kg ha^{-1}	533.33	18	9599.94
		Labour day^{-1}	10	290	2900
2.	Weeding & pruning	Labour day^{-1}	15	290	4350
3.	Harvesting of fruits	Labour day^{-1}	25	290	7250
	Working capital				30893.86
	Interest on working capital@ 14 annum				2162.57
				Total	33056.43

Appendix IV: Yield attributes, yield and economic of custard apple tree

Fruit tree	Average no. of fruits tree (ha^{-1})	Average no. of fruits tree^{-1}	Fruit yield tree (kg^{-1})	Average weight of fruit (gm)	Fruit yield kg (ha^{-1})	Rate of fruit (kg^{-1}) (₹)	Gross income from fruit tree (₹)
Custard apple	400	37.5	8.0625	215	3225	40	129000

Appendix V: Effect of nutrient management applied to mungbean on economic of custard apple tree

Fruit tree	Cost of cultivation	Gross return	Net return	B:C ratio
Custard apple	33056.43	129000	95943.57	2.90