

Effect of different levels of Phosphorus and Phosphate
Solubilizing Bacteria (PSB) inoculation on growth and
yield of Lentil (*Lens culinaris* Medik.) under Bael
(*Aegle marmelos* L.) based Agri-horti system

काशी हिन्दू
विश्वविद्यालय



BANARAS HINDU
UNIVERSITY

BHU
capital of knowledge

THESIS

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

Master of Science (Agriculture)
in
Agroforestry

Submitted by

Anuj Jain

Supervisor

Prof. J. P. Singh

Co-Supervisor

Dr. Savita Dewangan

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

ID. No. 19430AGF004

2021

Enrolment No. 413089

Dr. Jitendra Pratap Singh

Professor

Phone No.: + 91 9415256850 (M)

E-mail: jpratapsng@gmail.com

DEPARTMENT OF AGRONOMY

Institute of Agricultural Sciences

Banaras Hindu University

Varanasi- 221005, U.P. (India)

Ref. No.

Date

CERTIFICATE

To

The Registrar (Academic),

Banaras Hindu University,

Varanasi – 221 005 (India)

Through: The Head,
Department of Agronomy,
Institute of Agricultural Sciences,
BHU, Varanasi- 221005, U.P. (India)

Sir,

I have great pleasure in forwarding the thesis entitled **“Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system”** submitted by **Mr. Anuj Jain**, Examination Roll No. **19430AGF004**, in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in **Agroforestry**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that he has completed the requisite residential requirements as contained in the statutes of the university.

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

Thanking you,

Yours faithfully

Forwarded by

Head

(J. P. Singh)

Supervisor

Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system



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VARANASI – 221005**

ID.No. 19430 AGF 004

2021

Enrolment No. 413089

APPROVED BY MEMBERS OF ADVISORY COMMITTEE

Chairman and Supervisor	Dr. J. P. Singh Professor Department of Agronomy, Institute of Agricultural Sciences Banaras Hindu University, Varanasi – 221005
Co-supervisor	Dr. Savita Dewangan Assistant Professor Department of Agronomy Rajiv Gandhi South Campus, Barkachha, Mirzapur
Member	Dr. S. K. Verma Assistant Professor Department of Agronomy, Institute of Agricultural Sciences, BHU.
Member	Dr. S. K. Rajpoot Assistant Professor Department of Agronomy, Institute of Agricultural Sciences, BHU.
Member	Dr. Ashish M. Latare Assistant Professor Department of Soil Science and Agricultural Chemistry, Rajiv Gandhi South Campus, Barkachha, Mirzapur.
External Examiner	

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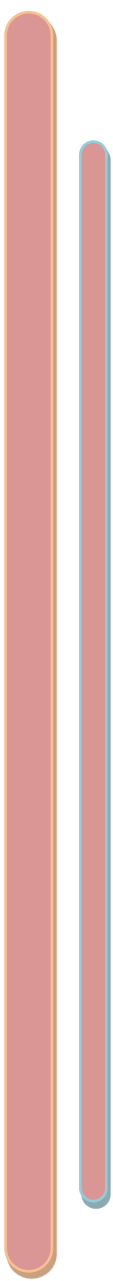
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Date:

Place: BHU

(Anuj Jain)



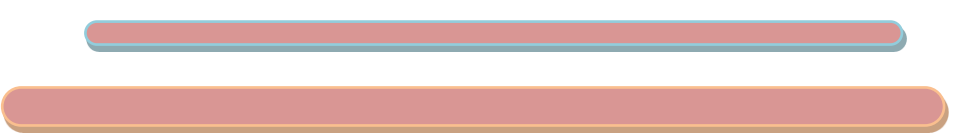
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ABBREVIATIONS AND SYMBOLS USED

Symbol	Legend
%	Per cent
@	At the rate of
₹	Rupees
₹ ha ⁻¹	Rupees per hectare
±	Plus or Minus
-1 or /	Per
cm	Centimeter
d.f.	Degree of Freedom
DAS	Days after sowing
dSm ⁻¹	Deci Siemens per meter
e.g.	For example
EC	Electric Conductivity
et al.	And others
etc	and the rest
Fig.	Figure (s)
FYM	Farm yard manure
g	Gram
ha	Hectare
HI	Harvest Index
i.e.	That is
K	Potassium
kg	Kilogram (s)
kg/ha or kg ha ⁻¹	Kilogram per hectare
m	Meter (s)
M ha	Million hectares
Max.	Maximum
mm	Millimeter
Mo	Molybdenum
MSS	Mean sum of square
N	Nitrogen
no	Number (s)
NS	Non-significant
NS	Non-significant
°C	Degree of centigrade
PSB	Phosphate-solubilizing bacteria
R.G.S.C.	Rajiv Gandhi South Campus
RBD	Randomized Block Design
RDF	Recommended dose of fertilizer
RDP	Recommended dose of Phosphorus
RH	Relative humidity
Rh	<i>Rhizobium</i>
S	Significant
S.S.	Sum of Square
SEm±	Standard error of mean
Viz.	Namely

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INTRODUCTION

Agroforestry is defined as the deliberately planting of perennial trees on the same unit of land as agricultural crops and animals, either in some form of spatial mixture or orders, with a significant interaction (both positive and negative) between the woody and nonwoody components of the system, for ecological or economic reasons (Nair 1984). Agroforestry helps in the rejuvenation of unproductive degraded land on one hand and also increases farm income on the other hand. Agroforestry supports in checking soil erosion and runoff which ultimately helps in the prevention of soil moisture, organic matter and nutrients. The roots of the trees help in obtaining the optimum physical properties of soil. As compared to agriculture crops, trees are more efficient in the recycling soil nutrients. Due to the increase in pollution, change in the climate is the major problem facing by all living organisms, here agroforestry emerges as a very beneficial system that helps in maintaining food security and fix the harmful effect of climate change. Agroforestry practices can reduce farmer vulnerability to climate change (Thorlakson *et al.* 2012)

Among all the components of agroforestry, the agri-horticultural system is one of the most practiced system followed from an ancient time where fruiting trees are grown along with agricultural crops. The tree also provides fuel woods, fodder, and other necessary commodities. Many fruit trees like banana, papaya, aonla, guava, bael can deliberately grow in an agri-horticultural system. Due to the short period time of fruiting and high net return tree⁻¹, farmers adopt fruiting trees for plantation. Different types of trees are suited for a different agroclimatic zone. This system reduces the risk of complete losses of the farmer in case of crop failure.

Bael (*Aegle marmelos* L.) comes under the family rutaceae, having a height from 6 to 10 m with sharp thorns. Flowers are greyish-white with sweet-scented. It is also known as belva, holy fruit tree, shripal, bael and wood apple. Trees are adapted to a wide range of climate and soil whereas good sandy loam soil, sunny situation and warm humid climate is the most suitable for proper growth of the tree. Bael is

generally propagated with seed at the beginning of monsoon in June-July. At initial, the fruit is deep green which turns yellow at the time of ripening. Bael fruit is hard globose in shape. Bael has aesthetic importance used in worship of lord maha Shiva. Fruit is also highly rich in nutrients like protein, beta-carotene, and vitamin C. Due to antioxidant, anti-inflammatory and laxative properties, it is widely used for medicinal purposes.

Pulses are one of the most important and second most grown crops after cereals in India. India is the largest producer and consumer of pulses in the world. The pulses production during 2019-20 is estimated about at 23.02 million tonnes. Madhya Pradesh is the highest pulses producing state in India followed by Rajasthan. Madhya Pradesh produces 32.14% and Rajasthan produces 13% of the total pulse production in India.

Generally, pulses have a high content of protein. Grains of legumes are used for human as well as for animal consumption. Legumes are the primary and major source of protein in the vegan diet and dairy substitutes. Other than protein, pulses also contain dietary fiber, carbohydrate and dietary minerals. Other than nutritive value, pulses also help in maintaining the physical, chemical and biological properties of soil. In most legume, nodules are present, where nitrogen-fixing rhizobia are present as organelle-like structures inside their root host cells helps in nitrogen fixation in soil from the atmosphere (Schwember *et. al* 2019).

Among the pulses, lentil is one of the most grown crops in India. India holds rank 1st in the area under lentil cultivation and 2nd in terms of production after Canada. Total lentil production in the year 2019-20 was 1096.5 tonnes, where Uttar Pradesh has the highest production of lentil 452.8 tonnes followed by Madhya Pradesh 294.48 tonnes. Lentil is grown in the winter season and has high nutritive value. The seeds of lentil have a higher content of protein, carbohydrates, fiber and manganese. A cup of lentil (198 grams) contains 230 calories, 17.9 grams of protein, 15.6 grams of fiber and folate (vitamin B9). Seed are consumed as “daal”. In several regions, it is consumed as soup, lentil flour is used for making stews, purees, and mixed with other grain flour for making bread and cake and as a food for infants.

After nitrogen, phosphorus is the second most important nutrient required by the plants in the term of quantitative amount. Phosphorus is one of the essential plant nutrients needed for all major developmental processes and also for reproduction in plants. Phosphorus is available in great extent in the soil, in both organic and inorganic form, but mostly present in an insoluble form which cannot be absorbed by the plants. Phosphorus plays a vital role in root development in legume crops, development of proper root system and provides better growth to the plant (Mitran *et al.* 2018). Some important molecules present in the plant cell as nucleic acid, proteins, lipid, adenylate and sugar contain phosphorus which are required for the proper functioning of a cell (Zhang *et al.* 2014). Phosphorus involves in multiple processes, including generation of energy, photosynthesis, nucleic acid synthesis, glycolysis, membrane synthesis and stability, activation and inactivation of enzymes, signaling and nitrogen fixation (Vance *et al.* 2003). Many studies reveal that there is more requirement of phosphorus in nodule containing legumes than non-symbiotic plants, and also found that that higher concentration of phosphorus increases higher nitrogen fixation rates in plants (Rotaru *et al.* 2009).

The quantity of phosphorus present in the soil is insufficient to support the vegetative and reproductive growth of the plant. When phosphorus is applied in the soil as fertilizer, due to fixation and microbial activity is gets immobilized in nature. Thus, only 20-30% of applied phosphorus is available to the plant and the rest is lost. Nearly, 90% of phosphorus is applied to the soil is in inorganic fertilizer form obtained from rock phosphate which gets immobilized and unavailable to plants in a very short time (Cordell and Drangert 2009). The shortage of phosphorus causes considerable yield loss in leguminous (Mitran *et al.* 2018). Since a huge amount of chemical phosphorus fertilizer is applied to gain maximum yield which deteriorates the quality of the soil and also causes an unfavorable impact on the environment as well as on the economy. Therefore, it is necessary to find out sustainable strategies to mitigate the harmful effect of chemical fertilizers.

Some bacterial species have a natural potential to solubilize soil phosphorus. Phosphate Solubilizing Bacteria (PSB) as an inoculant improves the availability of phosphorus to the crop and increases the yield. Phosphate Solubilizing

microorganisms have capacity to change the complex or insoluble phosphorus to soluble phosphorus through various mechanisms like chelation, acidification, exchange reaction and polymeric substance formation which can be uptake by crops (Zaidi *et al.* 2017). A large number of bacterial species is found to make a beneficial effect on plants. Several Phosphate Solubilizing Bacterial species such as *Pseudomonas*, *Bacillus*, *Enterobacter*, and *Azospirillum* are reported beneficial in phosphorus fixation (Kumari *et al.* 2009). Phosphate Solubilizing Bacteria can be inoculated by treating seeds or by mixing them with soil. Several studies have also reported that on inoculation with Phosphate Solubilizing Bacteria, there is a significant influence on plant growth parameters such as field emergence, height of the plant, numbers of root nodules plant⁻¹, length of root, and also on yield and yield attributing parameters (Singh *et al.* 2011).

A beneficial interaction has been observed between bael and lentil crop because of some factors such as bael biomass can add by pruning material, leaf litters and root residues which adds organic matter, nitrogen content, improves soil condition and therefore, increases the productivity of lentil. Due to shading caused by tree, there is a reduction of temperature and because of lower temperature, there is a reduction in vapor pressure deficit. Reduction in vapor pressure deficit causes a lower transpiration rate and thereby increases the water availability to the crop. The microclimate of bael orchard increase soil moisture condition in the field. The residue left by the lentil crop is added as an organic matter to the soil and this organic matter is utilized by the bael tree. Lentil also helps to fix atmospheric nitrogen to the soil through rhizobium which is also available to bael trees.

Keeping these facts into consideration, the present experiment entitled “**Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system**” was conducted with following objectives:

- To find out the response of phosphorus and PSB inoculation levels on growth and yield of lentil (*Lens culinaris* Medik.) under bael (*Aegle marmelos* L.) based agri-horti system.
- To determine the uptake of nitrogen, phosphorus and potassium by lentil (*Lens culinaris* Medik.) crop under bael (*Aegle marmelos* L.) based agri-horti system.
- To workout out the economics of treatments under bael based agri-horti system.



REVIEW OF LITERATURE

The relevant literature pertaining to different aspects of present research entitled “**Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system**” has been reviewed in this chapter.

2.1 Effect of phosphorus fertilizer

2.1.1 Effect of phosphorus fertilizer on growth

Zeidan *et al.* (2007) conducted an experiment during rabi season in 2003-04 and 2004-05 at the experimental farm of the National Research Centre at Nubariatoto to study the effect of organic manure and four levels of phosphorus on lentil and observed that on raising phosphorus from 0 to 60 kg ha⁻¹, there was a significant increase in plant height, number of the branches plant⁻¹, the number of pods plant⁻¹ and ultimately increase in the yield.

Rasheed *et al.* (2010) determine the performance of three lentil genotypes with four different levels of phosphorus (0, 40, 60 and 80 kg ha⁻¹) and concluded the result that a higher rate of phosphorus (80 kg ha⁻¹) showed the best positive result in terms of physiological trait and growth attributes.

Ayub *et al.* (2012) evaluate the effect of different levels of phosphorus and potassium on forage yield and quality parameters of cluster bean at the agronomic research area, University of Agriculture, Faisalabad. They apply combine phosphorus and potassium in eight different mixtures i.e., 0-0 (T1), 25-0 (T2), 25- 25 (T3), 40-40 (T4), 55-55 (T5), 70-70 (T6), 85-85 (T7) and 100-100 (T8) kg ha⁻¹ and observed that characters like plant height, the diameter of stem, branches plant⁻¹, leaf area index, crude protein and crude fiber were significantly improved with the phosphorus-potassium application at higher levels. They also stated that on the application of 85-

85 P₂O₅ and K₂O kg ha⁻¹, the highest number of branches plant⁻¹, leaf area index and dry matter were obtained.

Hojjat *et al.* (2013) experimented to determine the effect of combined application of complex fertilizer on nitrogen fixation by lentil. They took two levels of nitrogen (0 and 30 kg ha⁻¹) and phosphorus (0 and 50 kg ha⁻¹) and reported that on increasing the fertilizer level, there was a considerable increased in nodulation, nitrogen fixation, growth and yields on different genotypes of lentil.

Yadav *et al.* (2014) studied the growth, yield and quality of chickpea (*Cicer arietinum* L.) as influenced by phosphorus levels and bio-fertilizers under late sown conditions at Narendra Deva University of Agriculture and Technology, Faizabad. The results showed that the growth parameters viz., the height of plant, leaf area index, dry matter accumulation plant⁻¹ and number of branches plant⁻¹ were increased with each incremental levels of phosphorus from 0 to 90 kg P₂O₅ ha⁻¹. However, a non-significant effect was observed with application of 90 kg P₂O₅ ha⁻¹ as compared to 60 kg P₂O₅ ha⁻¹ in chickpea.

Pingoliya *et al.* (2015) investigate the impact of phosphorus and iron on protein and chlorophyll content in chickpea (*Cicer arietinum* L.) at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. They reported that application of phosphorus at higher rates elicited significant crop response with respect to symbiotic parameters which are nodulation, leghemoglobin content and nitrogenase activity.

Biswa *et al.* (2015) evaluated the result of the conjoint application of biofertilizer and phosphorus levels on growth, nodulation, nutrient uptake and productivity on lentil with four levels of phosphorus (0, 20, 40 and 60 kg ha⁻¹) and found that the application of 60 kg P₂O₅ ha⁻¹ recorded the maximum plant height (38.5 cm) at harvest and dry matter accumulation plant⁻¹ (125.47 g).

Narinder Singh and Guriqbal Singh (2016) showed in a review of the response of lentil to phosphorus that the more phosphorus application stimulates the

plant to extend the main root and lateral root length that allows the plant to absorb a huge volume of water from deeper soil layers. The interdependent parameters i.e., nodulation, nodule dry weight and leghemoglobin content were influenced by higher-level of phosphorus application.

Ali et al. (2017) researched to evaluate the response of lentil to various levels of phosphorus (40, 60, 80, 100 and 120 kg ha⁻¹) and zinc level at agricultural research farm, University of Agriculture, Peshawar and concluded that the number of pods plant⁻¹, test weight, seed yield and seed recovery percentage were influenced by various doses of zinc and phosphorus. More number of pods plant⁻¹ (118) and (122), thousand grain weight (30 g) and (29.6 g), grain yield (2021.3 kg ha⁻¹) and (2047.5 kg ha⁻¹) and maximum seed recovery of 69% were obtained from the plots received 100 and 120 kg phosphorus ha⁻¹ respectively.

Mitran et al. (2018) stated that phosphorus plays an important role in root development, nutrient uptake, provides energy for biological nitrogen fixation and growth of legume crops.

Singh et al. (2018) evaluate the effect of phosphorus, sulphur and biofertilizer on the growth and yield of chickpea (*Cicer arietinum* L.) at Narendra Deva University of Agriculture and Technology, Faizabad. They found that application of phosphorus at 60 kg P₂O₅ ha⁻¹ in chickpea significantly increased the growth parameters viz. plant height (43.74 cm), number of branches plant⁻¹ (16.42), number of root nodules plant⁻¹ (36.89) and dry weight (33.00 g) over the control.

2.1.2 Effect of phosphorus fertilizer on yield

Sharar et al. (2003) conducted an experiment on different combinations of nitrogen and phosphorus on the growth and yield of three varieties of lentil. They took four different combinations of nitrogen and phosphorus which were 0-0, 25-60, 37-90 and 50-120 nitrogen and phosphorus kg ha⁻¹ respectively. They observed that the highest number of pods plant⁻¹ (63.83) and seed yield (2265.37 kg ha⁻¹) were observed on the application of 50 kg nitrogen and 120 kg phosphorus ha⁻¹. They also observed

that the highest numbers of pods plant⁻¹ were found on application of higher levels of phosphorus and nitrogen.

Zeidan *et al.* (2007) concluded result that increasing the level of phosphorus from 0 to 60 kg ha⁻¹ increases the number of branches plant⁻¹, increases plant height, number of pods plant⁻¹, the weight of 1000 seeds, seed yield and also increases straw yield of lentil.

Togay *et al.* (2008) experimented on lentil with three different levels of phosphorus (0, 30 and 60 kg ha⁻¹) and four levels of molybdenum found that the highest grain yield was obtained on application of 60 kg phosphorus ha⁻¹ along with 6 kg molybdenum ha⁻¹. They also revealed that the number of pods plant⁻¹, number of seeds pod⁻¹ and weight of 1000 seeds were also higher on the application of 60 kg phosphorus ha⁻¹ and the lowest value were found under control.

Sadeghipour *et al.* (2010) performed an experiment to investigate the effect of different levels of phosphorus and nitrogen on yield and yield characteristics of mungbean (*Vigna radiata*) in randomize complete block design with three replications. They took five levels of nitrogen (0, 30, 60, 90 and 120 kg ha⁻¹) and six levels of phosphorus (0, 30, 60, 90, 120 and 150 kg ha⁻¹). Yield attribute and yield significantly increased with the higher application of phosphorus and nitrogen. The highest seed yield (224.2 g m⁻²) was found on application of 90 kg nitrogen ha⁻¹ and phosphorus at 120 kg ha⁻¹.

Ali *et al.* (2010) investigated the response of mungbean (*Vigna radiata*) to phosphorus fertilizer in arid conditions. The treatments were composed of control, 30 kg P₂O₅ ha⁻¹, 57 kg P₂O₅ ha⁻¹, 84 kg P₂O₅ ha⁻¹ along with a starter dose of nitrogen. They revealed that all levels of phosphatic fertilizer show a significant impact on mungbean over control. Phosphorus application at 84 kg P₂O₅ ha⁻¹ obtained the highest yield attributes and grain yield over other levels of phosphorus fertilizer.

Barua *et al.* (2011) investigated on lentil with five different levels of phosphorus which were control (P₀), 25% RDP (P₁), 50% RDP (P₂), 75% RDP (P₃)

and (P₄) 100% recommended dose phosphorus which was tri-super phosphate at 85 kg ha⁻¹ along with compost of mimosa. They found that phosphorus had a significant effect on various plant characters. The highest seed yield was observed in P₄ treatment (1464.17 kg ha⁻¹) over other treatments whereas the lowest yield was observed in P₀ treatment.

Singh et al. (2011) studied the effect of nutrition level on the growth and yield of lentil. They took four different combinations of nitrogen and phosphorus which were control, 9.4 kg N ha⁻¹ with 30 kg P₂O₅ ha⁻¹, 12.5 kg N ha⁻¹ with 40 P₂O₅ ha⁻¹ and 15.6 kg N with 50 kg P₂O₅ ha⁻¹ and observed that number of nodules and dry weight of nodules plant⁻¹, the height of the plant, shoot dry weight, the number of branches plant⁻¹, 100 seed weight, grain and biological yield were increased on increasing the levels of phosphorus and nitrogen.

Datta et al. (2013) experimented on different levels of phosphorus fertilizer and three different varieties of lentil (*lens culinaris*) at the agronomy field laboratory, Bangladesh, Agricultural University, Mymensingh from October 2009 to March 2010. They took four different levels of phosphorus which were 0 kg P₂O₅ ha⁻¹ (P₀), 15 kg P₂O₅ ha⁻¹ (P₁₅), 30 kg P₂O₅ ha⁻¹ (P₃₀) and 45 kg P₂O₅ ha⁻¹ (P₄₅) and found that phosphorus fertilizer had a significant effect on all plant characters except that of test weight of lentil grains. They found that the highest number of seeds pod⁻¹ (1.707) were found in P₄₅ treatment and the lowest were found in P₀ treatment. Similarly, the highest seed yield (1222 kg ha⁻¹) was found in treatment P₄₅ and the lowest yield (893 kg ha⁻¹) in P₀ treatment.

Dashadi et al. (2013) performed an experiment on two different cultivars of lentil with three levels of phosphorus which were 0, 50 and 100 kg P₂O₅ ha⁻¹ and three levels of zinc. They found that phosphorus had a significant effect on the plant height, the number of pods plant⁻¹, hundred seed weight and seed yield of lentil where the maximum yield was obtained on increasing levels of phosphorus and obtained highest on the application of 100 kg P₂O₅ ha⁻¹.

Choubey et al. (2013) revealed that the highest value for growth parameter, yield attributes and seed yield was observed under the treatment 60 kg P₂O₅ ha⁻¹ along with 20 kg S ha⁻¹ in lentil.

Shukla et al. (2017) studied the effect of phosphorus level and crop geometry on chickpea (*Cicer arietinum* L.) at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur and found that spacing of 45 cm x 15 cm with phosphorus at 60 kg P₂O₅ ha⁻¹ recorded the uppermost grain yield (13.15 qha⁻¹) followed by 30 cm x 15 cm spacing along with 60 kg P₂O₅ ha⁻¹ (12.05 qha⁻¹) and the lowest yield was recorded with 30 cm x 15 cm spacing in association with 0 kg P₂O₅ ha⁻¹.

Singh et al. (2017) studied the effect of phosphorus fertilizer application on chickpea (*Cicer arietinum* L.) in sunflower-chickpea cropping system at the agricultural farm of Amar Singh (P.G.) College, Lakhaoti, Bulandshah and found that on applying a higher level of phosphorus 60 kg P₂O₅ ha⁻¹ in chickpea significantly increased dry matter accumulation plant⁻¹ (9.48 g) and seed yield (2129.4 kg ha⁻¹) as compared to control.

Pandey et al. (2019) investigated yield attributing character, yield and nitrogen uptake of lentil influenced by phosphorus and sulphur level. The experiment was composed of four levels of phosphorus which were 0, 40, 60 and 80 kg P₂O₅ ha⁻¹ and three levels of sulphur 0, 30 and 60 kg S ha⁻¹. They observed that all the growth characters except height increases up to 80 kg P₂O₅ ha⁻¹. Yield attributing characters and yield was increased with increasing doses of phosphorus and sulphur. A significant increase in the yield and yield attributing character was recorded at 60 kg phosphorus ha⁻¹ and 30 sulphur kg ha⁻¹.

2.1.3 Effect of phosphorus fertilizer on nutrient uptake

Zeidan et al. (2007) observed that an increase in phosphorus level 60 kg ha⁻¹ obtained higher protein content, potassium content, iron and zinc (ppm) content in the seed of lentil plant. 60 kg P₂O₅ ha⁻¹ gave the highest levels of protein, phosphorus, potassium, iron, manganese and zinc contents in seeds as compared with 0, 30 and 45 kg P₂O₅ ha⁻¹.

Niri et al. (2010) evaluated the effect of nitrogen and phosphorus on the yield and protein content of lentil in dryland conditions. The experiment was consisting of three levels of nitrogen (0, 25 and 50 kg N ha⁻¹) and three levels of phosphorus (0, 40 and 60 P₂O₅ ha⁻¹). They stated that the application of phosphorus with 40 kg P₂O₅ ha⁻¹ found higher nitrogen and phosphorus content in grain.

Ahmed et al. (2011) carried out an experiment to evaluate the effect of superphosphate and Arbuscular Mycorrhizal Fungus *Glomus mosseae* on phosphorus and arsenic uptake in lentil (*Lens culinaris* Medik.). They found that inoculation with AM fungus *Glomous moasses* increases plant height, shoot dry weight, shoot/root phosphorus concentration. Superphosphate interaction with fungus reduces the role of mycorrhizal infection in terms of enhancing phosphorus nutrition. They also reported that superphosphate increases phosphorus and arsenic uptake and decreased the role of the mycorrhizal association.

Biswa et al. (2015) studied the effect of biofertilizers [untreated control, *Rhizobium*, PSB (Phosphate Solubilizing Bacteria) and *Rhizobium* + PSB] with four levels of phosphorus (0, 30, 45 and 60 kg P₂O₅ ha⁻¹) on growth, nodulation, productivity and nutrient content of lentil at Agricultural Research Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal. They found that application of 60 kg P₂O₅ ha⁻¹ recorded the highest uptake of nitrogen (32.87 and 24.99 kg ha⁻¹ in stalk and grain, respectively), phosphorus (6.61 and 4.77 kg ha⁻¹ in stalk and grain, respectively) and potassium (15.71 and 7.49 kg ha⁻¹ in stalk and grain, respectively) at harvest.

Balai et al. (2017) researched at the Agronomy farm, College of Agriculture, Bikaner, an experiment was done on chickpea (*Cicer aritenium* L.) to find the impact of phosphorus and zinc fertilizer on nutrient content, absorption, quality, and soil fertility status. They took four phosphorus levels (control, 20, 40, and 60 kg P₂O₅ ha⁻¹) and three zinc levels (control, 3.0 and 6.0 kg ha⁻¹). With the application of phosphorus 40 kg P₂O₅ ha⁻¹, there was a considerable rise in nitrogen content and absorption, according to the findings. There was a considerable increase in phosphorus content

and uptake in chickpea straw and grain after applying 60 and 40 kg P_2O_5 ha⁻¹ of phosphorus.

2.2 Effect of PSB

2.2.1 Effect of PSB on growth

Kumari et al. (2009) evaluated the effect of PSB on morphological characteristics of lentil. They inoculated seeds with three levels of PSB (10 g, 20 g and 30 g) in 2 kg of soil and one control on two varieties of lentil JL-3 and NDL-92. The result revealed that there were a greater number of branches, more plant height, a greater number of flowers and dry weights plant⁻¹ were observed on inoculation with PSB over control.

Singh et al. (2011) investigated the influence of Phosphate Solubilizing Bacterial for the enhancement of plant growth and seed yield in lentil. The experiment consists of three strains of PSB which were RMV1, RMV4 and RPB3 were tested through seed inoculation for plant growth, nodulation and seed yield in lentil. Results revealed that all strains had a significant effect on growth parameters such as plant height, number of branches, number of nodules, dry weight of nodules and also on yield attributes and yield of lentil over un-inoculated.

Tagore et al. (2013) determine the effect of *Rhizobium* and Phosphate Solubilizing Bacterial inoculants on interdependent traits such as nodule, leghemoglobin, and yield of chickpea (*Cicer arietinum* L.) genotypes at experimental farm, college of agriculture, Indore, Madhya Pradesh. They found that on the combine application of *Rhizobium* along with PSB, effective results were obtained on number of nodules plant⁻¹ (27.66 nodule plant⁻¹), nodule fresh weight (144.90 mg plant⁻¹) and nodule dry weight (74.30 mg plant⁻¹).

Pandey et al. (2016) undertook a split-plot design experiment to see how integrated phosphorus treatment affects lentil growth, production, and quality. The treatment combination consists of three levels of phosphorus (0, 40 and 80 kg P_2O_5 ha⁻¹) and three modes of PSB application which were soil application, seed

inoculation including control and sulphur application 20 kg S ha⁻¹ with control. They found that phosphorus 80 kg P₂O₅ ha⁻¹ along with seed inoculation with PSB has more net income and benefit-cost ratio. They also reported that seed inoculation with PSB increases growth, yield attributes, seed yield and protein yield.

Singh et al. (2018) investigated the effect of inoculation on lentil with PSB, plant growth-promoting rhizobacteria and *Rhizobium* on the productivity of lentil. They performed the experiment in randomize block design by treating seeds singly or in combination with biofertilizers. They found that seed treatment with *Rhizobium* in combination with PSB and plant growth-promoting rhizobacteria had improved nodulation, growth and yield of lentil.

Singh et al. (2018) determine the growth and yield of lentil on treating seeds with Phosphate Solubilizing Chryseobacterium sp. PSR 10 and uninoculated with different levels of N and P and concluded that seed inoculated with PSB had better plant height, agronomical parameter, amount of chlorophyll and phosphorus content significantly over control.

Singh et al. (2018) work on the effect sulphur, phosphorus and biofertilizer on the growth and yield of chickpea (*Cicer arietinum* L.) at Narendra Deva University of Agriculture and Technology, Faizabad. They revealed that PSB inoculation significantly increased the growth attributes of chickpea over un-inoculated. The plant height (38.21cm), number of branches plant⁻¹ (14.20), number of root nodules plant⁻¹ (28.61) and dry matter accumulation plant⁻¹ (29.53 g) were observed higher on inoculation with PSB over un-inoculated.

2.2.2 Effect of PSB on yield

Bera et al. (2013) investigated the response of biofertilizer and homo-brassinolide on growth, relative water content and yield of lentil (*Lens culinaris* Medik). They took four different levels of biofertilizer composed of control (no inoculation), Vascular Arbuscular Mycorrhiza (VAM), PSB and PSB along with VAM along with two sprays of brassinolide. Significant increase was observed on the application of biofertilizer on various growth characters like plant height,

accumulation of dry matter plant⁻¹ and yield characters like the number of pods plant⁻¹, test weight, grain yield, biological yield and harvesting index. The results revealed that a higher grain yield of lentil was observed on the combine application of PSB along with VAM and two spray of brassinoliade.

Kumar et al. (2014) conducted an experiment to know the yield, protein content, nutrient content and uptake of chickpea (*Cicer arietinum* L.) as influenced by different levels of fertilizers and bio-fertilizers at N. M. College of Agriculture, Navsari and reported that the crop sown with *Rhizobium* and PSB both as seed treatment showed significant improvement in seed yield (1824 kg ha⁻¹) and straw yield (2709 kg ha⁻¹) but remained at par with *Rhizobium* as seed treatment along with PSB as soil application and *Rhizobium* as seed treatment along with VAM as soil application.

Ansari et al. (2015) examined the combined effect of different biofertilizers which were *Rhizobium*, PSB and VAM on lentil at Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. They took five different treatments as Un-inoculated (T1), *Rhizobium* (T2), PSB with *Rhizobium* (T3), VAM with *Rhizobium* (T4) and *Rhizobium* with PSB and VAM (T5). They found that maximum nodulations plant⁻¹ (8.80, 13.50 and 5.00) was recorded in T5 treatment at an interval of 30, 60 and 90 days after sowing and also maximum test weight (32 g), grain yield (23.8 g microplot⁻¹) and straw yield (26.20 g microplot⁻¹) was recorded on combine application of *Rhizobium*, PSB and VAM on lentil.

Prajapati et al. (2017) find out the effect of integrated phosphorus management on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.) They revealed results that different bio-fertilizers, PSB (Phosphorus solubilizing bacteria) + AM (Arbuscular mycorrhiza) observed significantly the maximum plant height, number of branches plant⁻¹, plant spread, dry matter production plant⁻¹ (23.65 g), number of root nodules plant⁻¹ (25.19), number of pods plant⁻¹ (52.50), 100-seed weight (12.28 g plant⁻¹), seed yield (18.94 qha⁻¹) and straw yield (26.48 qha⁻¹). They reported that integrated use of 75 % RDP through SSP + 25 % RDP through rock

phosphate and combined use of AM with PSB can be used for the better yield of chickpea.

Singh et al. (2018) evaluated the influence of phosphorus and PSB on the green gram and found that all growth parameters which was plant height, dry matter accumulation plant⁻¹, leaf area index, yield and yield attributes viz. biological yield, seed yield, straw yield, number of pods plant⁻¹ and number of seeds pod⁻¹ were recorded maximum in combine application of phosphorus and PSB.

Dwivedi et al. (2018) carried out an experiment to evaluate the effect of phosphorus, sulphur and biofertilizers on the growth, yield and quality of lentil (*Lens culinaris*). They reported that height of the plant, number of branches plant⁻¹, number of pods plant⁻¹ and 1000 seeds weight were observed the maximum on the application of 60 kg P₂O₅ ha⁻¹ with seed inoculation with *Rhizobium* + PSB biofertilizers over 30 kg P₂O₅ha⁻¹.

2.2.3 Effect of PSB on nutrient uptake

Laharia et al. (2019) evaluated the combined effect of phosphorus and PSB on production, nutrient utilization efficiency, and nutrient uptake by chickpea (*Cicer arietinum* L.) at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The results showed that applying 75% RDF coupled with PSB increased chickpea yield and total nitrogen, phosphorus, and potassium uptake substantially. They also exposed that increasing the phosphorus level from 75% RDF to 125% RDF of phosphorus in combination with PSB results in increased nutritional absorption. They discovered that when phosphorus was applied at 125% RDF together with PSB, nitrogen and potassium utilization efficiency was increased.

2.3 Combine effect of phosphorus fertilizer and PSB

2.3.1 Combine effect of phosphorus fertilizer and PSB on growth

Sekhon et al. (2010) determine the effect of phosphorus, PSB and farm yard manure on microbial traits, growth and yield of lentil and stated that on the addition of phosphorus and PSB increases the dry weight of nodules in chickpea.

Kumawat *et al.* (2009) studied the influence of organic manures, PSB and phosphorus fertilization on the growth and yield of kharif mungbean and found that combined application of phosphorus, vermicompost and PSB had significantly increased growth attribute i.e., plant height, the number of branches plant⁻¹, dry matter accumulation plant⁻¹, chlorophyll content, effective nodules plant⁻¹, dry weight of nodules plant⁻¹, total nodules and finally seed yield (8.09 qha⁻¹) of mungbean.

Yadav *et al.* (2017) investigated the response of phosphorus, *Rhizobium* and Phosphate Solubilizing Bacteria interaction studies on growth, nodulation and yield of lentil at Crop Research Farm, Nawabganj, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur in factorial randomized block design. They took four levels of phosphorus (0, 40, 80 and 120 kg P₂O₅ ha⁻¹) and seed inoculation with *Rhizobium* and dual inoculation with *Rhizobium* with PSB. They found that growth and yield attributes like the number of branches plant⁻¹, the number of pods plant⁻¹, grain and straw yield were increased significantly on applying phosphorus up to 120 kg P₂O₅ ha⁻¹ and results were at par on applying 80 kg P₂O₅ ha⁻¹. On inoculation of seeds with *Rhizobium* along with PSB produces significantly taller plants with a greater number of branches plant⁻¹, number of root nodules⁻¹, greater number pods plant⁻¹, test weight of seed, grain and straw yield of lentil. The Combined effect of 80 kg P₂O₅ ha⁻¹ along with *Rhizobium* and PSB had produced significantly higher grain yield.

Singh *et al.* (2018) carried out research on yield enhancement and phosphorus economy in lentil with integrated use of phosphorus, *Rhizobium* and plant growth-promoting rhizobacteria. They took four levels of phosphorous (0, 20, 30, and 40 kg P₂O₅ ha⁻¹) along with biofertilizers, *Rhizobium*, plant growth-promoting rhizobacteria (*Pseudomonas fluorescens*), *Rhizobium* with PGPR, and uninoculated in lentil. They discovered that applying 40 kg P₂O₅ ha⁻¹ of phosphorus produced the most nodules plant⁻¹, dry weight of nodules plant⁻¹, leghemoglobin concentration in chlorophyll, yield characteristics and grain yield. They also revealed that inoculating seeds with biofertilizer and plant growth-promoting rhizobacteria outperformed over uninoculated controls in terms of growth and yield measures. They also stated that

combining the effects of phosphorus, biofertilizer, and PGPR can help to reduce the need for phosphate fertilizer.

Katiyar et al. (2020) experimented on the impact of *Rhizobium* and PSB inoculation on growth, yield attributes and yield of chickpea and found that on the combined application of *Rhizobium* along with PSB and DAP, the maximum plant height, number of branches plant⁻¹, number of nodules plant⁻¹, fresh and dry weight and dry matter accumulation plant⁻¹ were observed.

2.3.2 Combine effect of phosphorus fertilizer and PSB on yield

Singh et al. (2014) worked on different levels of phosphorus and inoculation and un-inoculation of the seeds with PSB in lentil. They found that phosphorus significantly improves seed yield, nodules, root length and its dry weight, phosphorus content in the grain and straw. Seed inoculation with PSB not only increased phosphorus use efficiency but also improve seed and straw yield.

Pandey et al. (2016) revealed that on the application of phosphorus 80 kg P₂O₅ ha⁻¹ enhances plant growth, seed yield and protein yield along with seed inoculation with PSB and had also a positive effect on the growth, yield and protein content of seeds of lentil.

Rasool et al. (2016) laid out an experiment to evaluate the effect of biofertilizer which were PSB and *Rhizobium* in combination with different levels of phosphorus fertilizer on lentil and found that the highest number of primary branches plant⁻¹, seed plant⁻¹ and seed yield were recorded in dual inoculation of biofertilizer with phosphorus 60 kg P₂O₅ ha⁻¹.

Chauhan et al. (2017) investigated the combined impact of phosphorus and PSB on chickpea (*Cicer arietinum*) regarding growth, yield, and quality parameter in Jalalpur village in Morena district of Madhya Pradesh using a randomized block design involving three replications. They reported that applying 60 kg P₂O₅ ha⁻¹ combined with PSB enhanced plant height, number of branches plant⁻¹, number and

dry weight of nodules, dry weight of shoot plant⁻¹, as well as crop yield characteristics and yield.

Chaurasiya et al. (2020) figure out the effect of PSB inoculation with and without phosphorus and sulphur application on the productivity of mungbean (*Vigna radiata* L.) and concluded that the best result was obtained on combined application of phosphorus, PSB and sulphur on growth and yield of mungbean.

2.3.2 Combine effect of phosphorus fertilizer and PSB on nutrient uptake

Gupta et al. (2006) measure the influence of phosphorus fertilization in combination with bio-fertilizer inoculation on the yield and quality of urdbean (*Vigna mungo*). They found that seed inoculation with PSB had significantly increased yield and also protein content and nitrogen and phosphorus uptake over uninoculated. Phosphorus at 60 kg P₂O₅ ha⁻¹ also increased nitrogen and phosphorus uptake in straw and seeds.

Dhakal et al. (2016) use three sources of nutrients on green gram which were inorganic, organic and biofertilizer. Among different combinations, treatment with 75% RDF + 2.5 t ha⁻¹ vermicompost along with *Rhizobium* and PSB had significantly increased the number of nodules plant⁻¹, dry weight of nodules plant⁻¹, nutrient content and available nitrogen, phosphorus, potassium and organic carbon after harvesting in soil.

Chauhan et al. (2017) performed an experiment to find out the combined effect of phosphorus and PSB on the growth, yield and quality of chickpea (*Cicer arietinum*) conducted at Jalalpur village of Morena district with seven treatments in randomized block design with three replications. They reported that uptake of nitrogen and phosphorus by chickpea grain was increased significantly with combined application of phosphorus and PSB.

Bhavya et al. (2018) conducted a field experiment to evaluate the effect of phosphorus levels, biofertilizers (Phosphate Solubilizing Bacteria) and organic manures (vermicompost) on green gram (*Vigna radiata*) with three replications in

randomize block design having 12 treatments composed of three levels of phosphorus (0, 75 and 100 % RDF) and its integration with PSB (500 g ha⁻¹ seeds) and vermicompost to determine effect on the yield, nutrient concentration and nutrient uptake at flowering and at harvest. They found that on application 100% RDF along with seed inoculation with PSB and application of vermicompost 5 t ha⁻¹ had significantly increased nitrogen, phosphorus, potassium and sulphur concentration in grain, haulm and their uptake in green gram.

Singh et al. (2019) determine the impact of integrated nutrient management on growth characteristics, nutrient accumulation, production unit⁻¹ area and profitability of lentil (*Lens culinaris* Medik.). They apply recommended dose of nutrients (RDN, 12.5 kg N ha⁻¹ with 40 kg P₂O₅ ha⁻¹) along with 25 kg ZnSO₄ ha⁻¹ and seed inoculation with biofertilizers [*Rhizobium* along with PSB and plant growth promoting rhizobacteria] with 1.0 g ammonium molybdate kg⁻¹. Nitrogen, phosphorus and potassium in the grains and straw were significantly improved where recommended dose of nitrogen was applied in combination with seed inoculation with *Rhizobium* and PSB, basal application of ZnSO₄ and seed treatment with 1 g ammonium molybdate than their sole applications.

2.4 Interaction among crop and tree components in agroforestry system

Srinivasan et al. (2010) found that the combination of leguminous trees enhanced the available N, P, K content of the soil as compared to individual coconut plots.

Chandrakar et al. (2014) observed that the highest net return ₹ 18143 ha⁻¹ were obtained in case of 100% recommended dose of fertilizer along with 25 kg zinc sulphate recorded under the alley cropping with blackgram in bael based agri-horti system.

Kumar et al. (2015) investigated the effect of phosphorus on nutrient content, nutrient uptake and economics of blackgram under bael apple based Agri-horti

system. The result revealed that total nutrient uptake ha^{-1} was considerably highest with application of phosphorus up to 75 kg ha^{-1} .

Dhewaj *et al.* (2015) experimented at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu university, Barkachha, Mirzapur, Uttar Pradesh to investigate the effect of various levels of phosphorus and PSB on the growth characteristics and yield of green gram (*Vigna radiata* L.) under custard apple (*Annona squamosa* L.) based agri- horti system. The results revealed that the mean maximum plant height, dry matter accumulation plant^{-1} and number of trifoliate leaves plant^{-1} under dual inoculation of PSB (S_1) + PSB (S_2) along with $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ at all successive stage which were significantly superior to control, $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and $30 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ during the investigation.



MATERIAL AND METHODS

The current experiment entitled “**Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system**” was carried out during the winter season of 2019-20 at Agricultural Research farm of Rajiv Gandhi South Campus, Barkachha (BHU), Mirzapur, Uttar Pradesh. The various field and climatic condition under which the experiment was carried out is described in this chapter.

3.1 Experimental site

The experiment was performed at Agricultural Research farm of Rajiv Gandhi South Campus, Barkachha (BHU), Mirzapur (25.146° N ,82.569° S) which is situated on Robertsganj highway in Vindhyan region of district Mirzapur. The farm is located 8 km Southwest of Mirzapur. The district is located 427 meters above the mean sea level covering a total area of 4521 km². A variety of agricultural, horticultural, medicinal and aromatic crops are grown on the research farm. Research field come under rainfed condition and has sandy loam soil with low fertility status.

3.2 Climate and Weather

The climate of RGSC, Mirzapur is typically semi-arid, characterized by extreme temperatures both in summer and winter with low rainfall and moderate humidity. May and June are the hottest months with mean maximum temperature in summer ranging from 43.09°C to 48.02°C. However, the coldest month is January with the mean minimum temperature in the winter season ranging from 4°C to 7°C. In this region, the monsoon is usually starts from the third week of June and lasts up to the end of October. The mean humidity remains 65% which rises up to 90.85% from July to September and falls from April to June. The area occasionally receives some showers of winter cyclonic rain during December to February. The normal annual precipitation of this region is about 950 mm.

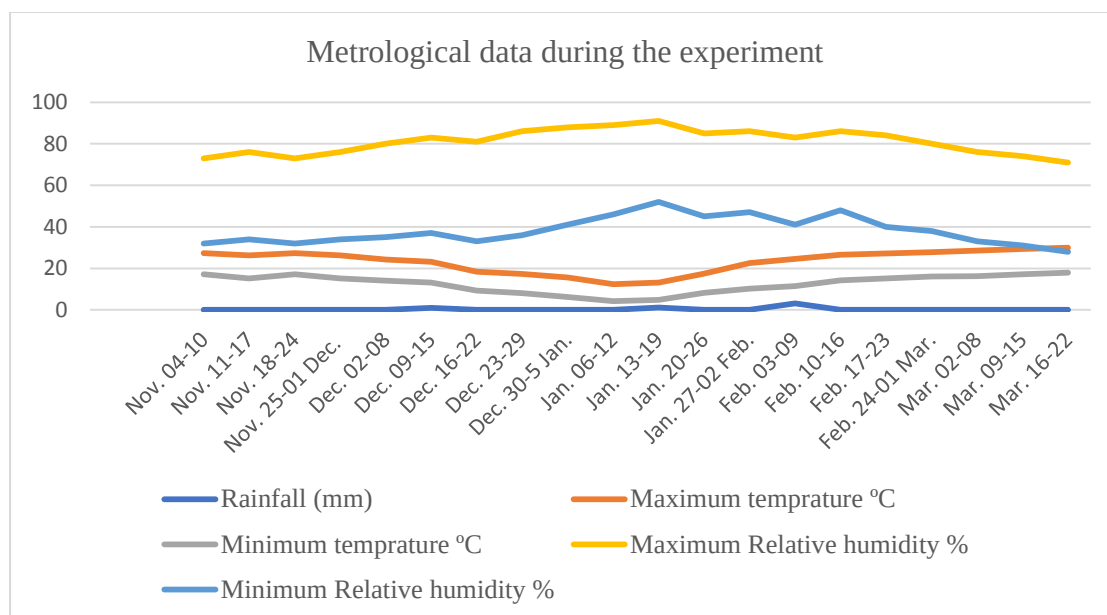
3.3 Weather during the crop season

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

Table 3.1: Mean week-wise meteorological data during the experiment (November, 2019 to March 2020)

Julian Weeks	Month and date	Rainfall (mm)	Temperature °C		Relative humidity %	
			Max.	Min.	Max.	Min.
45	Nov. 04-10	0	27.4	17.1	73	32
46	Nov. 11-17	0	26.2	15.2	76	34
47	Nov. 18-24	0	27.4	17.1	73	32
48	Nov. 25-01 Dec.	0	26.2	15.2	76	34
49	Dec. 02-08	0	24.3	14.1	80	35
50	Dec. 09-15	1	23.2	13.2	83	37
51	Dec. 16-22	0	18.4	9.3	81	33
52	Dec. 23-29	0	17.3	8.1	86	36
1	Dec. 30-5 Jan.	0	15.6	6.2	88	41
2	Jan. 06-12	0	12.4	4.2	89	46
3	Jan. 13-19	1.2	13.2	4.9	91	52
4	Jan. 20-26	0	17.5	8.3	85	45
5	Jan. 27-02 Feb.	0	22.6	10.2	86	47
6	Feb. 03-09	3.2	24.6	11.5	83	41
7	Feb. 10-16	0	26.5	14.2	86	48
8	Feb. 17-23	0	27.2	15.1	84	40
9	Feb. 24-01 Mar.	0	27.8	16.1	80	38
10	Mar. 02-08	0	28.6	16.3	76	33
11	Mar. 09-15	0	29.4	17.1	74	31
12	Mar. 16-22	0	30	17.9	71	28

Fig. 3.1: Mean week-wise meteorological data during the experiment (November, 2019 to March 2020)



3.3.1 Temperature (°C)

The monthly average minimum and maximum temperature, during the phase of crop growth, ranges from 4.2⁰C to 30⁰C respectively. The minimum temperature 4.2⁰C was observed in January, whereas the maximum temperature 30⁰C was observed in the month of March.

3.3.2 Relative humidity (%)

The weekly mean maximum and minimum relative humidity, during the period of crop the growth ranges from 91% to 71% and 52% to 28% respectively.

3.4 Soil analysis

Soil samples were collected from a depth of 15 cm to recognize the physical and chemical properties of soil. Proper measures were taken at the time of collection of samples. Samples were collected with the help of a soil auger. Collected soil samples were dried in laboratory, pass through 2.0 mm sieve and further analysis were proceed. The results of the analysis are presented in table 3.2

Table 3.2: Mechanical and physio-chemical analysis of soil of the experimental field

Particulars	Unit	Value	Method
1. Mechanical analysis			
Sand	(%)	50.36	International Pipette Method (Piper, 1966)
Silt	(%)	33.43	
Clay	(%)	15.52	
Textural class		Sandy loam	Texture class (Black <i>et al.</i> , 1965)
2. Physical constants			
Bulk density	(Mg m ⁻³)	1.44	Pycnometer bottle Black <i>et al.</i> (1965)
Particle density	(Mg m ⁻³)	2.52	Pycnometer bottle Black <i>et al.</i> (1965)
3. Chemical properties			
Organic carbon	(%)	0.38	Rapid titration method (Walkley and Black, 1934)
Available N	(kg ha ⁻¹)	162.35	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P ₂ O ₅	(kg ha ⁻¹)	17.12	0.5 M NaHCO ₃ extractable (Olsen <i>et al.</i> 1954)
Available K ₂ O	(kg ha ⁻¹)	157.6	1N neutral ammonium acetate method (Piper, 1966)
pH		6.7	Glass Electrode pH meter (Jackson, 1973)
Electrical conductivity	(dS m ⁻¹)	0.26	Systronics Electrical conductivity meter (Jackson, 1973)

3.5 Cropping history of the field experimentation

The cropping history of the field experimentation of the previous five years are enlisted in table 3.3

Table 3.3: Cropping history of experimental field

Year	<i>Kharif</i>	<i>Rabi</i>
2015-16	Mung bean	Fallow
2016-17	Peal millet	Fallow
2017-18	Sesame	Fallow
2018-19	Sesame	Fallow
2019-2020	Sesame	Lentil

3.6 Experimental detail

The experiment was carried out during rabi season under bael based agri-horti system. Bael trees were planted at a standard spacing of 7*7 meters between rows and plants respectively. The experiment was performed in Factorial Randomize Block Design with three different levels of phosphorus and PSB respectively. Treatment combinations are listed in table 3.4.

Table 3.4: Combinations of treatments and their symbol

S. No.	Treatment	Symbol	Treatment details
1.	T ₁	P ₁ B ₁	*RDF + 20 kg P ₂ O ₅ ha ⁻¹ + 0mL PSB kg ⁻¹ seed
2.	T ₂	P ₂ B ₁	*RDF + 40 kg P ₂ O ₅ ha ⁻¹ + 0mL PSB kg ⁻¹ seed
3.	T ₃	P ₃ B ₁	*RDF + 60 kg P ₂ O ₅ ha ⁻¹ + 0mL PSB kg ⁻¹ seed
4.	T ₄	P ₁ B ₂	*RDF + 20 kg P ₂ O ₅ ha ⁻¹ + 5mL PSB kg ⁻¹ seed
5.	T ₅	P ₂ B ₂	*RDF + 40 kg P ₂ O ₅ ha ⁻¹ + 5mL PSB kg ⁻¹ seed
6.	T ₆	P ₃ B ₂	*RDF + 60 kg P ₂ O ₅ ha ⁻¹ + 5mL PSB kg ⁻¹ seed
7.	T ₇	P ₁ B ₃	*RDF + 20 kg P ₂ O ₅ ha ⁻¹ + 10mL PSB kg ⁻¹ seed
8.	T ₈	P ₂ B ₃	*RDF + 40 kg P ₂ O ₅ ha ⁻¹ + 10mL PSB kg ⁻¹ seed
9.	T ₉	P ₃ B ₃	*RDF + 60 kg P ₂ O ₅ ha ⁻¹ + 10mL PSB kg ⁻¹ seed

Where,

P₁ = 20 kg P₂O₅ ha⁻¹, P₂ = 40 kg P₂O₅ ha⁻¹, P₃ = 60 kg P₂O₅ ha⁻¹,

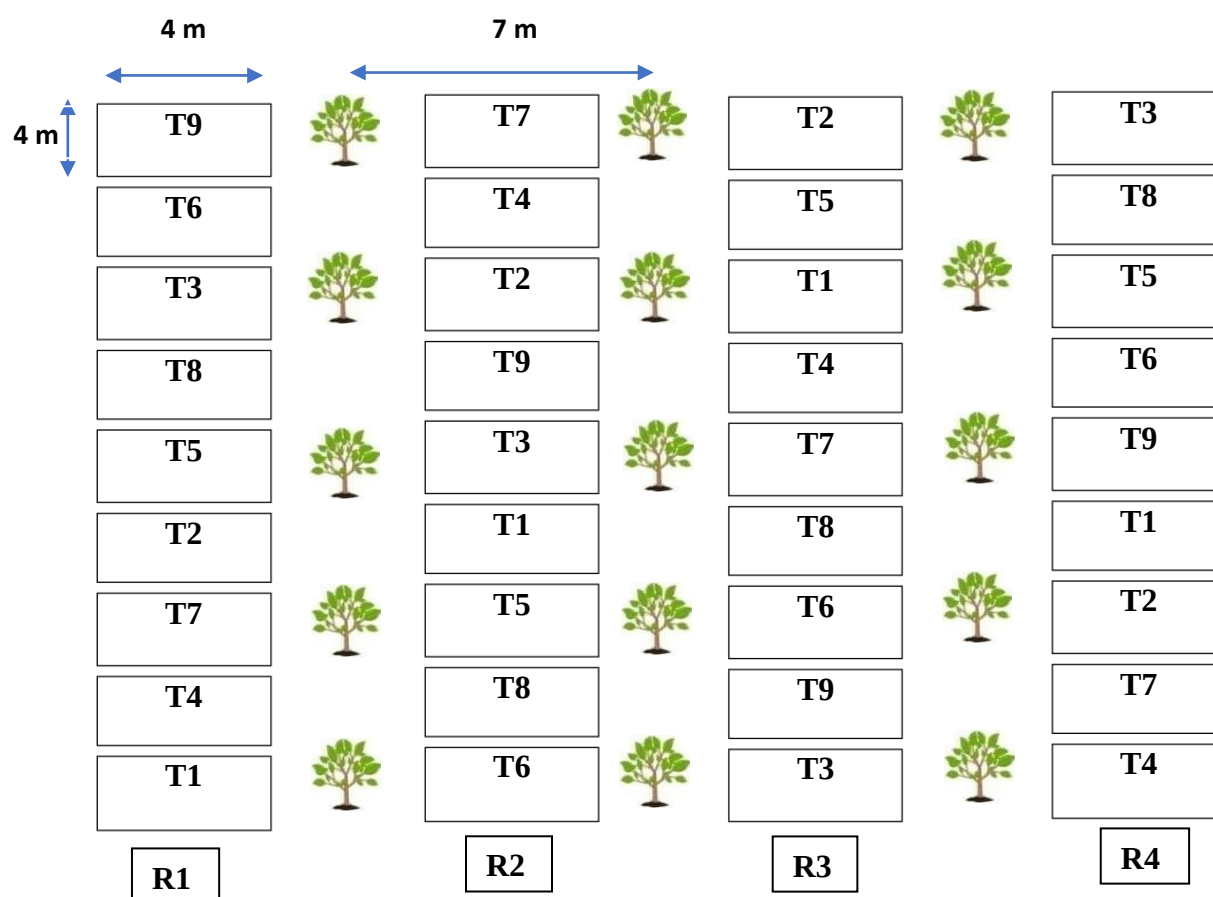
B₁ = 0mL PSB kg⁻¹ seed inoculation, B₂ = 5mL PSB kg⁻¹ seed inoculation,

B₃ = 10mL PSB kg⁻¹ seed inoculation

Table 3.5: Layout details

Site of Experiment	Agriculture Research Farm, RGSC
Season	Rabi
Experimental design	Factorial Randomized Block Design
No. of treatment	9
No. of replication	4
Total number of plots	$9 \times 4 = 36$
Block border	50 cm
Gross plot size	$4 \text{ m} \times 4 \text{ m} = 16 \text{ m}^2$
Net plot size	$3 \text{ m} \times 3 \text{ m} = 9 \text{ m}^2$
Row to row spacing	30 cm
Plant to plant spacing	5 cm
Crop	Lentil
Variety	HUL-57
Fruit crop	Bael
Bael spacing	$7 \times 7 \text{ m}$
Bael Variety	Narendra Bael-7
Year	2019-2020

Fig. 3.2: Layout plan of the field experiment



3.7 Selection of experiment materials

3.7.1 Variety (HUL-57)

The improved variety of lentil HUL-57 was developed by the dryland center, Varanasi and released by Central Varietal Committee as Malviya Vishwanath is recommended for north eastern plain zone of Uttar Pradesh. It is resistant to rust and moderately resistant to wilt. The spacing recommended is 30 cm in row to row and 5 cm in plant to plant and require fertilizer dose of 20 kg N ha⁻¹, 40 kg P ha⁻¹, 20 kg K ha⁻¹ and 20 kg S ha⁻¹.

3.7.2 Fertilizer application

The recommended doses of nitrogen (20 kg ha⁻¹), potassium (20 kg ha⁻¹) and sulphur (20 kg ha⁻¹) were applied to the field at the time of seed sowing. The three variable doses of phosphorus (P₂₀, P₄₀, and P₆₀ kg ha⁻¹) were also applied at the time of sowing according to the treatment. The source of nitrogen, phosphorus, potassium and sulphur were urea, diammonium phosphate, muriate of potash and sulphur granules respectively.

3.7.2.1 Urea

Urea is the most widely used nitrogen fertilizer. Urea contains the highest percentage of nitrogen (46%) among solid fertilizers. It contains nitrogen in amide form. This fertilizer is cheaper than any other solid nitrogenous fertilizer in India.

3.7.2.2 Diammonium Phosphate (DAP)

Diammonium phosphate (DAP; IUPAC name diammonium hydrogen phosphate) is one of a series of water-soluble ammonium phosphate salts that can be produced when ammonia reacts with phosphoric acid. DAP temporarily increases the soil pH, but over the long term, the treated ground becomes more acidic. It contains 46% of phosphorous and 18% of nitrogen.

3.7.2.3 Muriate of Potash (MOP)

Potassium chloride (KCl, or potassium salt) is a metal halide salt composed of potassium and chlorine. It is odorless and has a white or colorless vitreous crystal appearance. The solid dissolves readily in water, and its solutions have a salt-like taste. It contains 60% of potassium.

3.7.2.4 Sulphur granules

Sulphur granules contain 90% of sulphur which directly added nutrition to the soil and enhances plant growth.

3.7.3 Phosphate Solubilizing Bacteria (PSB)

Phosphate Solubilizing Bacteria (PSB) plays an important role in the mineralization of unavailable phosphorus into available forms, thereby, increases phosphorus uptake by plants which in turn increases productivity. These organisms can be used as bioinoculants for converting the insoluble native as well as fixed phosphorus into soluble form for the plants. Looking to the shortage and rising prices of chemical fertilizer, biofertilizers uses as bio-inoculants are the need of the present time.

3.8 Agronomic practices

The detailed cultural practices during the research work from field preparation to harvesting is given in the table 3.6

3.8.1 Land preparation

A good seedbed is required for the germination and growth of lentil plants. Seedbed was prepared by one-time ploughing of land with a tractor drawn cultivator followed by planking. Then the field was divided in respected plot areas according to the layout. 36 plots of the equal area were prepared and further experimental work was carried out.

Table 3.6: Schedule of crop operation

S.No.	Operation	Date
A	Pre-sowing operation	
1.	Palewa (pre-sowing irrigation)	10.11.2019
2.	Land preparation • Plough • Harrowing and planking	12.11.2019 12.11.2019
3.	Seed inoculation with PSB	13.11.2019
4.	Layout of the experiment	14.11.2019
B	Sowing operation	
1.	Fertilizer application and sowing	14.11.2019
C	Post sowing operation	
1.	Thinning of crop	1.12.2019
2.	Weeding • First weeding • Second weeding	09.12.2019 30.12.2019
3.	Irrigation • First irrigation • Second irrigation	14.12.2019 20.01.2020
4.	Harvesting	16.03.2020
5.	Threshing	20.03.2020
6.	Cleaning	21.03.2020

3.8.2 Seed Inoculation and Sowing

The seeds of variety HUL-57 were inoculated with PSB according to treatment. Seeds were treated with two concentrations which were 5mL and 10mL PSB kg⁻¹ seeds. The seeds were dried in shade for 3-5 hrs. Seeds sowing was done with the help of kudal at an optimum row to row 30 cm apart and plant to plant at 5 cm distance.

3.8.3 Intercultural operation

For maintaining the optimum plant population and to promote proper growth of the plant, thinning was done after 15 days after sowing. To reduce plant weed competition, weeding was done manually with the help of khurpi at 25 and 45 days after sowing. The irrigation was applied to the crop for maintaining moisture in the field. Two irrigations were given at 30 days after sowing and at 65 days after sowing.

3.8.4 Harvesting and threshing

The crop was harvested at the maturity stage nearly 120 days after sowing. The harvesting stage was observed by visual observation when ripen pods turns yellow. Harvesting was done manually with the help of sickle. The harvested plants were left in the field for drying. After 3-4 days, plants from each plot were carefully taken in separate bags to observe biometric observation. Before taking plants to the threshing floor, Bundle weight (grain + straw) was recorded. Threshing was done manually with hands.

3.9 Biometric observations

For collecting data based on biometric observation, five plants from each plot were selected randomly and tagging process was done. The readings were taken at the interval of 30 days after sowing. Four readings were taken at 30, 60, 90 days after sowing and at harvest. Yield and yield attributing characteristics were recorded as per requirement.

3.9.1 Growth Parameter of lentil

3.9.1.1 Plant height (cm)

The height of five randomly tagged plants was measured at 30, 60, 90 DAS and the harvesting stage. Plant height was measured from surface level to tip of the plant. The average values were calculated and expressed in centimeters (cm).

3.9.1.2 Number of branches plant⁻¹ (No.)

The total number of branches plant⁻¹ was counted with tagged plants from each plot at 30, 60, 90, DAS and at harvesting stage. The average number of branches plant⁻¹ was worked out.

3.9.1.3 Number of green leaves plant⁻¹ (No.)

The number of green leaves of individual plants were counted at 30, 60 and 90 DAS. The average number of green leaves plant⁻¹ was worked out.

3.9.1.4 Number of root nodules plant⁻¹ (No.)

The total number of root nodules plant⁻¹ were measured from the five random plants from each plot at 30 and 60 DAS. The plant was uprooted very carefully from the sample rows. The average number of root nodules plant⁻¹ was carried out.

3.9.1.5 Dry matter accumulation (g Plant⁻¹)

Randomly five plants were selected for calculation of dry matter accumulation plant⁻¹. The plants from each plot were uprooted and washed under running tap water and afterward dried in sunlight. The sundried plants were kept in the oven at 70°C for about 24 hours and then weighed. The observation was recorded subsequently at 30, 60, 90 DAS and harvest.

3.9.2 Yield Attributes of lentil

3.9.2.1 Number of pods⁻¹ (No.)

The total number of pods of the tagged plant was counted and an average number of pods were recorded.

3.9.2.2 Number of grains pod⁻¹ (No.)

Number of grains pod⁻¹ were counted by taking an average of five tagged plants from each plot. Their average number of seeds pod⁻¹ was worked out.

3.9.2.3 Test weight (g)

One thousand seeds were counted from the produce of each plot and were weighed with the help of an electronic weighing machine.

3.9.3 Yield

3.9.3.1 Grain yield (qha⁻¹)

Lentil grain yield was calculated after completion of threshing, winnowing, cleaning and drying processes. Grains from each net plot were weighed separately with the help of electronic weighing machine. Then calculated value was converted into qha⁻¹.

3.9.3.2 Straw yield (qha⁻¹)

The straw yield was calculated by separating the grain yield from the biological yield recorded per net plot and later converted into qha⁻¹.

3.9.3.3 Biological yield (qha⁻¹)

The biological yield refers to the total dry matter accumulation of the plant system. The biological yield was obtained by adding of grain and straw yield.

3.9.3.4 Harvest index (%)

The harvest index of lentil is expressed as the percentage of grain yield to the biological yield. It is obtained by using the formula as follows:

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

3.10 Nutrient analysis of plant materials

The plant and grain samples were collected from each plot for chemical estimation. The samples were oven dried at 70⁰C for 2 days or 48 hours and then plant material thus obtained was grind with the help of a grinder and passed through 40 mesh sieve and preserved individually for determination of nitrogen, phosphorus and potassium content and uptake.

3.10.1 Nutrient content (%)

3.10.1.1 Nitrogen content (%)

The plant and grain samples were analyzed separately for nitrogen content by Micro Kjeldahl method of digestion and distillation as outlined by Jackson 1973 and the results were expressed in percentage.

3.10.1.2 Phosphorus content (%)

The plant and grain sample were digested with di-acid mixture, nitric acid (HNO₃) and perchloric acid (HClO₄) in a 9:4 ratio on a volume basis. Phosphorus was estimated by vanado molybdo-phosphoric acid method followed by spectrophotometric determination (Jackson, 1973).

3.10.1.3 Potassium content (%)

The plant and grain samples were analyzed under a flame photometer for the estimation of potassium content by using a flame photometer method (Jackson 1973).

3.10.2 Nutrient uptake (kg ha⁻¹)

Nutrient uptake (nitrogen, phosphorus and potassium) of lentil were calculated in kg ha⁻¹ from their corresponding yield and nutrient content by using formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)} / 100$$

3.11 Quality characters

3.11.1 Protein content (%)

Protein content in grain and straw of lentil was calculated by multiplying the nitrogen content with factor 6.25 (AOAC, Washington 1960). Nitrogen content was estimated by micro-Kjeldahl method.

3.11.2 Protein yield (kg ha⁻¹)

Protein yield in grain and straw of lentil was calculated from grain and straw protein content multiplied by grain yield and straw yield respectively. It is measured in kg ha⁻¹.

$$\text{Protein yield (kg ha}^{-1}\text{)} = \text{Protein content (\%)} \times \text{yield (kg ha}^{-1}\text{)} / 100$$

3.12 Nutrient analysis of soil

The Initial soil of the experimental field was analyzed. Composite soil samples from five different places of an experimental area were collected before starting of the experiment to determine the initial status of the soil. Soil samples were taken from 10-15 cm depth and then mixed thoroughly for preparing composite soil samples. The composite soil samples were air dried, ground, sieved and used for estimation of chemical properties and residual nutrients status of the soil.

3.12.1 Soil pH

Soil pH was determined in a soil-water suspension in the ratio of 1:2.5 w/v and stirred at regular intervals for 30 minutes using fritz glass electrode pH meter (Jackson, 1973).

3.12.2 Electrical conductivity

The soil-water suspension prepared for the determination of pH was used to estimate the electrical conductivity of the soil. The soil suspension was allowed to settle till suspension become clear. Electrical conductivity was measured with the help of Systronics Electrical conductivity Meter and expressed as dS m^{-1} (Jackson, 1973). The scale reading (mmhos cm^{-1}) was converted to dS m^{-1} using the following formula.

$$\text{EC (dS m}^{-1}\text{)} = \text{Scale reading} \times 1000 \times \text{cell constant (1.0)}.$$

3.12.3 Available organic carbon in soil

In a 500mL conical flask, one gram of soil was taken and mixed with 10mL of 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution. Then 20mL of concentrated H_2SO_4 was added to the mixture and then flask was swirled 2-3 times and allowed to stand on an asbestos sheet for 30 minutes so that reaction takes place. With 200mL of distilled water the suspension was diluted and titrated, also add 10mL of orthophosphoric acid (H_3PO_4) and 1mL of diphenyl indicator to the solution. Finally, the solution was titrated against 0.5N Ferrous Ammonium Sulphate. Organic carbon was determined using chromic acid rapid titration method (Walkley and black, 1934). Organic carbon calculated by using following formula.

$$\text{Organic carbon in soil (\%)} = \frac{10(B-S)}{B} \times 0.003 \times \frac{100}{\text{Wt.of soil sample}}$$

Where, B = Volume of 0.5 N FAS solution used for blank titration.

S = Volume of 0.5 N FAS solution used for sample titration.

3.12.4 Available nitrogen in soil

Available nitrogen was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956). The procedure involves distilling the soil with alkaline potassium permanganate solution and determining ammonia released by titrating against 0.02N Sulphuric acid (H_2SO_4).

Calculation

$$\begin{aligned}\text{Mineralizable N in soil (kg ha}^{-1}\text{)} &= \frac{(S-B) \times 0.00028}{20} \times 10^6 \times 2.24 \\ &= (S - B) \times 31.36\end{aligned}$$

Where, S = Sample titration reading, B = Blank titration reading

3.12.5 Available phosphorus in soil

Available Phosphorus content was determined by using Olsen's reagent method (Olsen et al. 1954). 2.5 g soil transferred to a 250mL conical flask, then 50mL Olsen's reagent (0.5 M NaHCO₃) was added, then a pinch of Darco G-60 charcoal was added and shaken the content of flask for 30 minutes on a mechanical shaker and filtered by Whatman No.1 filter paper, then 10mL aliquot is taken in 25mL volumetric flask and 2-3 drop was added of P- nitrophenol indicator. Thereafter, 5 N H₂SO₄ was added drop by drop till the yellow color becomes colorless then 8mL of ascorbic acid solution was added and make the volume up to 25mL mark and wait for 10 minutes for appearance of blue color.

Calculation

$$\text{Available P (kg ha}^{-1}\text{)} = \frac{Q \times V \times 2.24 \times 10^6}{A \times S \times 10^6}$$

Where, Q = Quantity of P in µg read on X-axis against a sample reading,

V = Volume of extracting reagent used (mL),

A = Volume of aliquot used for color development (mL),

S = Weight of soil sample,

$$\text{Olsen's P (kg ha}^{-1}\text{)} = Q \times 8.96$$

3.12.6 Available potassium in soil

The available soil potassium content was determined by using the 1N ammonium acetate method (Jackson, 1973). 5 grams of soil was transferred to a 100mL conical flask and 25mL of 1N ammonium acetate solution was added and shaken for 5 minutes. The suspension was then filtered through WhatmanNo.1 filter paper and the concentration of potassium in the filtrate was measured using flame photometer.

Calculation

Dilution factor (DF) = 5 g soil was diluted with 25mL 1N Ammonium acetate (NH₄OAc) extractant.

Hence, DF = 5 times

$$\begin{aligned}\text{Available K}_2\text{O (kg ha}^{-1}\text{)} &= C \times \text{DF} \times 2.24, \\ &= C \times 5 \times 2.24 \\ &= C \times 11.2\end{aligned}$$

Where, C = Sample reading.

DF = Dilution factor.

3.13 Observation on bael (Fruit tree)

The following growth parameters of bael, situated at border of the plot, were recorded at the scheduled date.

3.13.1 Plant height (m)

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

3.13.2 Canopy (m)

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

3.13.3 Stem girth (cm)

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

3.13.4 Shading (m)

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

3.13.5 Yield (kg ha⁻¹)

The average number of fruits per tree of random five trees were calculated. After weighing their cumulative weight, it was converted into kg ha⁻¹ at the end of the experiment (month of March). It was plucked when the fruit color changed from green to yellow.

3.14 Economics

In preparing the cost of cultivation, it is compulsory to indicate the requirement of power (tractor and water pump) and labour (including family labour) for different operations, viz. ploughing, intercultural operation, plant protection, harvesting, threshing and inputs like seeds, chemicals (fertilizer and pesticides) etc. Treatment wise economics ₹ ha⁻¹ was calculated as per rates prevalent at the local market price.

3.14.1 Gross return (₹ ha⁻¹)

It is a total monetary value of the economic produce of seed and by products (such as straw) obtained from the lentil crop. The yield of lentil (grain and straw) was

converted into gross return in ₹ ha⁻¹ based on the current price prevailing in the market and approved for the sale of produce at local market.

$$\text{Gross return (₹ ha}^{-1}\text{)} = \text{yield of produce} \times \text{price of produce}$$

3.14.2 Net return (₹ ha⁻¹)

The net return was calculated by following formula.

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

3.14.3 Benefit-cost ratio

This index provides an estimate of the benefit derived after subtracting the expenditure incurred in adopting a particular cultivation practice. Benefit-cost ratio was calculated by following formula.

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

3.15 Statistical analysis

The observations recorded during the course of investigation were tabulated and analyzed statically to draw a valid conclusion. The data was analyzed as per standard procedure for “Analysis of variance” (ANOVA). The significance of treatment was tested by ‘F’ test (variance ratio). Standard error of mean was computed in all cases. The difference in the treatment mean was carried out by using Critical Difference (C.D.) at 5% level of probability where ‘F’ test showed significant difference among means by formula:

$$\text{C.D. at 5\%} = \text{S.E.m.} \pm \times \sqrt{2} \times t \text{ value at 5\% of error (a) degree of freedom.}$$

$$\text{S.E.m.} \pm = \sqrt{\frac{\text{Error sum of square}}{n}}$$

Table 3.7: ANOVA table for Factorial Randomized Block Design

Source of variation	D.F.	Sum of square	Mean sum of square	“F” calc.	“F” tabulated
Replication	3				
P	2				
B	2				
P*B	4				
Error	24				
Total	35				





Field view of experimental field

EXPERIMENTAL FINDINGS

The fields experimentation was carried out at research farm of Rajiv Gandhi South Campus, Barkachha (BHU), Mirzapur, (U.P.) entitled **“Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system”**. This chapter deals with different observation recorded at different time intervals is presented here on the basis of statistically analysis.

4.1 Growth parameters

4.1.1 Plant height (cm)

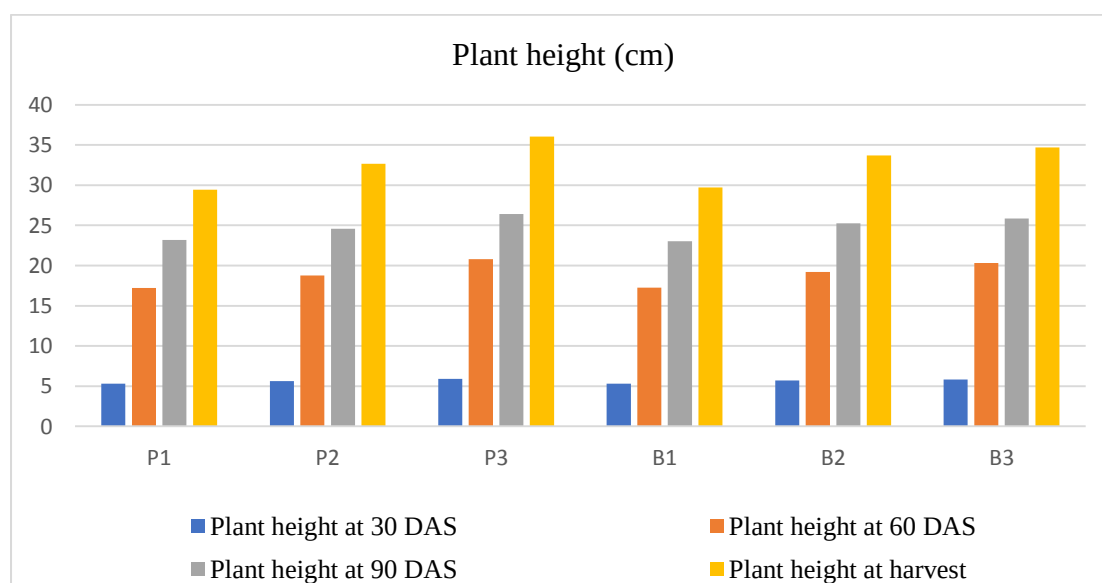
Table 4.1 and fig. 4.1 show the results of the plant height analysis. During the early stages of growth, the plant's height was rapidly raised, but later, the plant's growth rate was reduced.

At harvest, the maximum plant height (36.03 cm) was found when 60 kg P_2O_5 ha⁻¹ of phosphorus was applied, which was significantly higher than 40 kg P_2O_5 ha⁻¹ (32.67 cm) and 20 kg P_2O_5 ha⁻¹ (29.42 cm).

At harvest, the maximum plant height was reported on seed inoculation with PSB at 10mL PSB kg⁻¹ seed inoculation (34.68 cm), which was significantly higher than 0mL PSB kg⁻¹ seed (29.72 cm) but statistically comparable to 5mL PSB kg⁻¹ seed inoculation (33.71 cm).

Table 4.1: Effect of different levels of phosphorus and PSB inoculation on plant height (cm) of lentil under bael based agri-horti system

Treatment	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	5.33	17.2	23.17	29.42
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	5.62	18.76	24.6	32.67
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	5.9	20.8	26.4	36.03
SEm±	0.1	0.31	0.4	0.34
CD (P= 0.05)	0.3	0.91	1.18	1.01
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	5.31	17.25	23.03	29.72
B ₂ (5mL PSB kg ⁻¹ seed)	5.71	19.2	25.27	33.71
B ₃ (10mL PSB kg ⁻¹ seed)	5.83	20.31	25.87	34.68
SEm±	0.1	0.31	0.4	0.34
CD (P= 0.05)	0.3	0.91	1.18	1.01
Interaction	NS	NS	NS	S

Fig. 4.1: Effect of different levels of phosphorus and PSB inoculation on plant height (cm) of lentil under bael based agri-horti system

The interactive effect between PSB and phosphorus on plant height was found significant at harvesting. The data is shown in table 4.1a.

Table 4.1a: Interaction between levels of phosphorus and PSB inoculation on plant height (cm) of lentil crop at harvest under bael based agri-horti system.

Treatments	Interaction effect of P and PSB on plant height at harvest		
	P ₁	P ₂	P ₃
	(20 kg P ₂ O ₅ ha ⁻¹)	(40 kg P ₂ O ₅ ha ⁻¹)	(60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	28.28	29.18	31.70
B ₂ (5mL PSB kg ⁻¹ seed)	29.93	34.05	37.15
B ₃ (10mL PSB kg ⁻¹ seed)	30.05	34.78	39.23
SEm±		0.60	
CD (P= 0.05)		1.74	

Under the treatment 60 kg P₂O₅ ha⁻¹ along with 10mL PSB kg⁻¹ seed inoculation significantly increases the plant height of lentil crop (39.23 cm) as compared to other treatment combinations at harvest. The second highest plant height (37.15 cm) of lentil was found with 5 mL PSB kg⁻¹ seed inoculation at same phosphorus level. The least value of plant height (28.28 cm) was noticed under uninoculated seed and 20 kg P₂O₅ ha⁻¹ application.

4.1.2 Number of branches plant⁻¹ (No.)

Different treatments altered the number of branches plant⁻¹ at 30, 60, 90 DAS, and at harvest, as shown in table 4.2 and fig. 4.2.

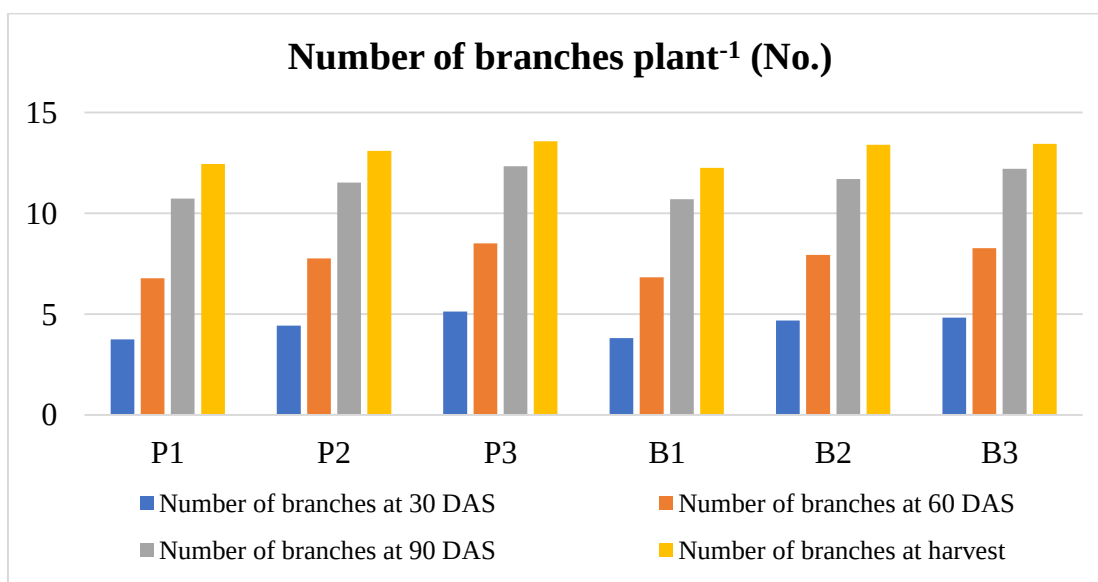
At harvest, the treatment 60 kg P₂O₅ ha⁻¹ (13.57 branches plant⁻¹) had recorded the maximum number of branches plant⁻¹, which were significantly greater than 20 kg P₂O₅ ha⁻¹ (12.44 branches plant⁻¹) but statistically at par 40 kg P₂O₅ ha⁻¹ (13.09 branches plant⁻¹).

The maximum number of branches plant⁻¹ (13.45 branches plant⁻¹) were seen at harvest when PSB was applied at 10mL kg⁻¹ of seed inoculation, which was significantly superior to 0mL PSB kg⁻¹ of seed (12.25 branches plant⁻¹) but statically at par with 5mL PSB kg⁻¹ of seed inoculation (13.4 branches plant⁻¹).

Table 4.2: Effect of different levels of phosphorus and PSB inoculation on the number of branches plant⁻¹ of lentil under bael based agri-horti system

Treatment	Number of branches plant ⁻¹ (No.)			
	30 DAS	60 DAS	90 DAS	At harvest
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	3.75	6.78	10.73	12.44
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	4.44	7.77	11.53	13.09
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	5.13	8.51	12.34	13.57
SEm±	0.07	0.14	0.19	0.21
CD (P= 0.05)	0.22	0.4	0.55	0.63
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	3.81	6.83	10.7	12.25
B ₂ (5mL PSB kg ⁻¹ seed)	4.68	7.94	11.7	13.4
B ₃ (10mL PSB kg ⁻¹ seed)	4.83	8.28	12.21	13.45
SEm±	0.07	0.14	0.19	0.21
CD (P= 0.05)	0.22	0.4	0.55	0.63
Interaction	NS	NS	NS	NS

Fig. 4.2: Effect of different levels of phosphorus and PSB inoculation on the number of branches plant⁻¹ of lentil under bael based agri-horti system



4.1.3 Number of green leaves plant⁻¹ (No.)

At 60 days following sowing, the highest number of green leaves plant⁻¹ was recorded. Leaves begin to turn yellow after a certain period of time. As a result, at 90 DAS and thereafter, the quantity of green leaves plant⁻¹ was diminished. Table 4.3 and fig. 4.3 illustrate the data.

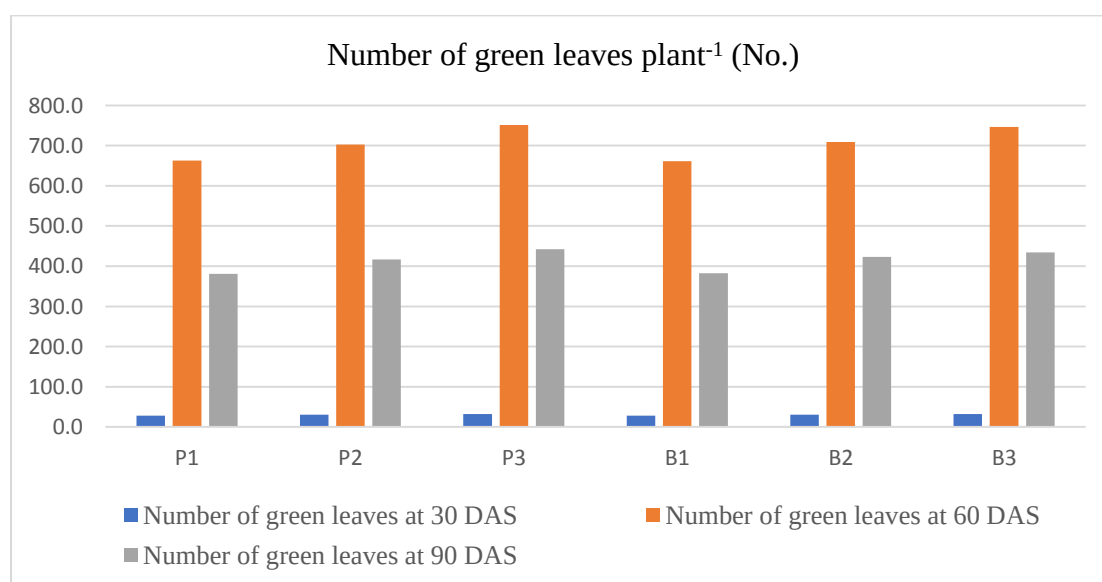
The number of green leaves plant⁻¹ at 60 DAS of lentil was greatly enhanced under varied amounts of phosphorus, according to the results. The highest number of green leaves plant⁻¹ were found on the application of 60 kg P₂O₅ ha⁻¹ (751.07 green leaves plant⁻¹), which were significantly higher than 40 kg P₂O₅ ha⁻¹ (702.28 green leaves plant⁻¹) and 20 kg P₂O₅ ha⁻¹ (662.73 green leaves plant⁻¹).

On seed inoculation with 10mL PSB kg⁻¹ seed (746.26 green leaves plant⁻¹), the highest number of green leaves plant⁻¹ were achieved, which were significantly greater than 5mL PSB kg⁻¹ seed (709 green leaves plant⁻¹) and 0mL PSB kg⁻¹ seed inoculation (660.83 green leaves plant⁻¹).

Table 4.3: Effect of different levels of phosphorus and PSB inoculation on the number of green leaves plant⁻¹ of lentil under bael based agri-horti system

Treatment	Number of Green leaves plant ⁻¹ (No.)		
	30 DAS	60 DAS	90 DAS
Levels of Phosphorus (kg ha⁻¹)			
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	28.18	662.73	379.18
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	30.29	702.28	416.09
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	32.19	751.07	440.71
SEm±	0.51	10.13	6.62
CD (P= 0.05)	1.48	29.57	19.31
Levels of PSB (mL kg⁻¹)			
B ₁ (0mL PSB kg ⁻¹ seed)	27.98	660.83	380.7
B ₂ (5mL PSB kg ⁻¹ seed)	30.77	709.00	422.37
B ₃ (10mL PSB kg ⁻¹ seed)	31.93	746.26	432.92
SEm±	0.51	10.13	6.62
CD (P= 0.05)	1.48	29.57	19.31
Interaction	NS	NS	NS

Fig. 4.3: Effect of different levels of phosphorus and PSB inoculation on the number of green leaves plant⁻¹ of lentil under bael based agri-horti system



4.1.4 Number of root nodules plant⁻¹ (No.)

The data presented in table 4.4 and fig. 4.4 shows that the number of root nodules plant⁻¹ were increased with advancement of crop growth from 30 to 60 DAS.

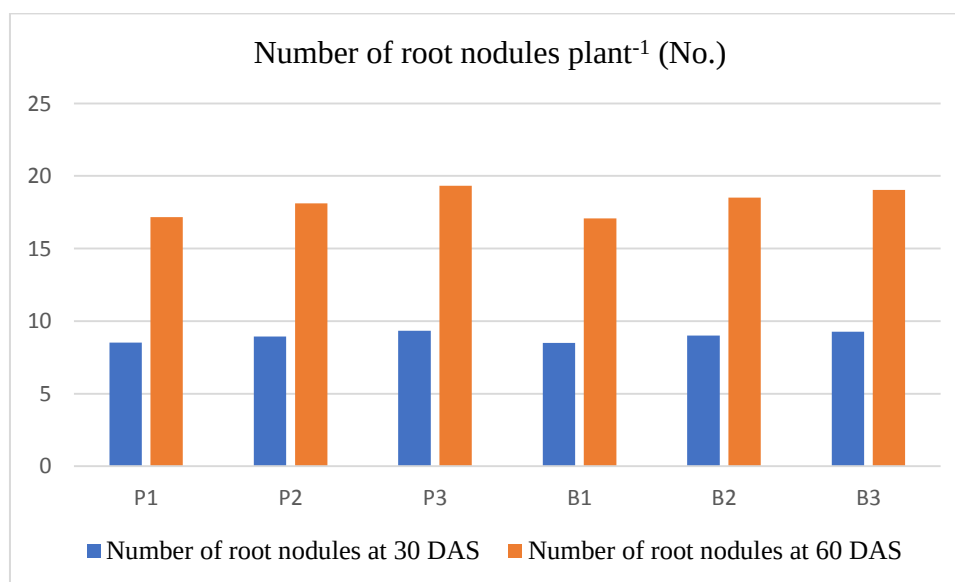
The superior amount of root nodules plant⁻¹ were observed at 60 DAS on the application of phosphorus at 60 kg P₂O₅ ha⁻¹ (19.32 nodules plant⁻¹) which were significantly superior over 40 kg P₂O₅ ha⁻¹ (18.12 nodules plant⁻¹) and 20 kg P₂O₅ ha⁻¹ (17.17 nodules plant⁻¹).

The maximum number of root nodules plant⁻¹ were found on seed inoculation with 10mL PSB kg⁻¹ seed (19.03 nodules plant⁻¹) which were significantly superior over 0mL PSB kg⁻¹ seed (17.08 nodules plant⁻¹) but remained statically at par with 5mL PSB kg⁻¹ seed inoculation (18.5 nodules plant⁻¹).

Table 4.4: Effect of different levels of phosphorus and PSB inoculation on the number of root nodules plant⁻¹ of lentil under bael based agri-horti system

Treatment	Root Nodules plant ⁻¹ (No.)	
	30 DAS	60 DAS
Levels of Phosphorus (kg ha⁻¹)		
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	8.53	17.17
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	8.93	18.12
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	9.33	19.32
SEm±	0.15	0.3
CD (P= 0.05)	0.43	0.87
Levels of PSB (mL kg⁻¹)		
B ₁ (0mL PSB kg ⁻¹ seed)	8.49	17.08
B ₂ (5mL PSB kg ⁻¹ seed)	9.01	18.5
B ₃ (10mL PSB kg ⁻¹ seed)	9.28	19.03
SEm±	0.15	0.3
CD (P= 0.05)	0.43	0.87
Interaction	NS	NS

Fig. 4.4: Effect of different levels of phosphorus and PSB inoculation on the number of root nodules plant⁻¹ of lentil under bael based agri-horti system



4.1.5 Dry matter accumulation plant⁻¹ (g plant⁻¹)

Dry matter accumulation plant⁻¹ was measured at 30 DAS, 60 DAS, 90 DAS, and at harvest. Table 4.5 and fig. 4.5 shows the data.

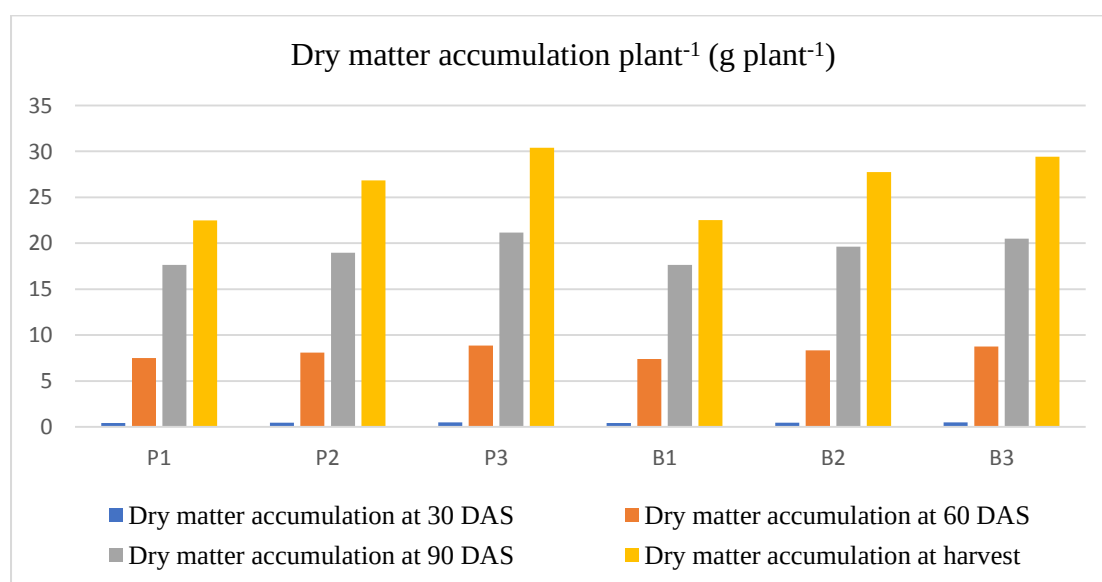
Dry matter accumulation plant⁻¹ was increased at every stage from germination to harvesting. In comparison to 90 DAS, 60 DAS, and 30 DAS, the highest amount of dry matter accumulation plant⁻¹ was observed at harvest. Phosphorus application at 60 kg P₂O₅ ha⁻¹ resulted in the maximum dry matter accumulation plant⁻¹ (30.4 g plant⁻¹) which was significantly superior over 40 kg P₂O₅ ha⁻¹ (26.83 g plant⁻¹) and 20 kg P₂O₅ ha⁻¹ (22.47 g plant⁻¹).

On seed inoculation with 10mL PSB kg⁻¹ seed recorded the maximum amount of dry matter accumulation plant⁻¹ at harvest (29.43 g plant⁻¹) which was significantly higher over 5mL PSB kg⁻¹ seed (27.74 g plant⁻¹) and 0mL PSB kg⁻¹ seed inoculation (22.53 g plant⁻¹).

Table 4.5: Effect of different levels of phosphorus and PSB inoculation on dry matter accumulation plant⁻¹ of lentil under bael based agri-horti system

Treatment	Dry Matter accumulation plant ⁻¹ (g plant ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	0.44	7.51	17.64	22.47
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	0.47	8.11	18.98	26.83
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	0.52	8.87	21.15	30.4
SEm±	0.01	0.21	0.39	0.38
CD (P= 0.05)	0.04	0.6	1.14	1.12
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	0.44	7.41	17.63	22.53
B ₂ (5mL PSB kg ⁻¹ seed)	0.48	8.33	19.63	27.74
B ₃ (10mL PSB kg ⁻¹ seed)	0.51	8.75	20.51	29.43
SEm±	0.01	0.21	0.39	0.38
CD (P= 0.05)	0.04	0.6	1.14	1.12
Interaction	NS	NS	NS	S

Fig. 4.5: Effect of different levels of phosphorus and PSB inoculation on dry matter accumulation plant⁻¹ of lentil under bael based agri-horti system



The interactive effect of PSB and phosphorus on dry matter accumulation plant^{-1} (g plant^{-1}) was found significant at harvest. The data is shown in table 4.5a.

Table 4.5a: Interaction between different levels of phosphorus and PSB inoculation on dry matter accumulation plant^{-1} (g plant^{-1}) of lentil crop at harvest under bael based agri-horti system

Treatments	Interaction effect of P and PSB on dry matter accumulation plant^{-1} at harvest		
	P ₁	P ₂	P ₃
	(20 kg P ₂ O ₅ ha ⁻¹)	(40 kg P ₂ O ₅ ha ⁻¹)	(60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	20.49	21.41	25.71
B ₂ (5mL PSB kg ⁻¹ seed)	22.97	28.43	31.82
B ₃ (10mL PSB kg ⁻¹ seed)	23.96	30.64	33.69
SEm±		0.51	
CD (P= 0.05)		1.5	

Under treatment 60 kg P₂O₅ ha⁻¹ along with 10mL PSB kg⁻¹ seed inoculation significantly increased the dry matter accumulation plant^{-1} of lentil crop (33.69 g plant^{-1}) as compared to the other treatment combinations at harvest. The second highest dry matter accumulation plant^{-1} (31.82 g plant^{-1}) of lentil was recorded on the application of 60 kg P₂O₅ ha⁻¹ along with 5mL PSB kg⁻¹ seed inoculation. The least dry matter accumulation plant^{-1} (20.49 g plant^{-1}) was observed under treatment 20 kg P₂O₅ ha⁻¹ alone.

4.2 Yield attributes

Yield attributing characters are important as they directly contribute in yield of crop and measured at the time of harvesting.

4.2.1 Number of pods plant⁻¹ (No.)

The number of pods plant⁻¹ have positive correlation with yield. The statically analyzed data is presented in table 4.6 and fig 4.6.

The number of pods plant⁻¹ were affected by different levels of phosphorus and PSB. The superior number of pods plants⁻¹ were observed in treatment 60 kg P₂O₅ ha⁻¹ (78.98 pods plant⁻¹) which were significantly exceeded to both the lower levels viz. 40 kg P₂O₅ ha⁻¹ (70.18 pods plant⁻¹) and 20 kg P₂O₅ ha⁻¹ (65.68 pods plant⁻¹).

With respect to PSB inoculation, 10mL PSB kg⁻¹ of seed inoculation recorded the maximum number of pods plant⁻¹ (77.37 pods plant⁻¹) which were significantly higher than 5mL PSB kg⁻¹ of seed (71.84 pods plant⁻¹) and 0mL PSB kg⁻¹ of seed inoculation (65.25 pods plant⁻¹).

4.2.2 Number of grains pod⁻¹

Table 4.6 and fig. 4.6 show how the quantity of grains pod⁻¹ fluctuates dramatically with different levels of phosphorus and PSB.

The number of grains pods⁻¹ grew when the amount of phosphorus was increased where phosphorus application at 60 kg P₂O₅ ha⁻¹ (1.5 grains pod⁻¹) resulted in the highest number of grains pod⁻¹ which were significantly greater than 40 kg P₂O₅ ha⁻¹ (1.36 grains pod⁻¹) and 20 kg P₂O₅ ha⁻¹ (1.18 grains pod⁻¹).

The application of 10mL PSB kg⁻¹ seed inoculation (1.46 grains pod⁻¹) produced the most grains pod⁻¹ which were found significantly superior over 0mL PSB kg⁻¹ seed inoculation (1.19 grains pod⁻¹) but remained statically at par with 5mL PSB kg⁻¹ of seed inoculation (1.40 grains pod⁻¹)

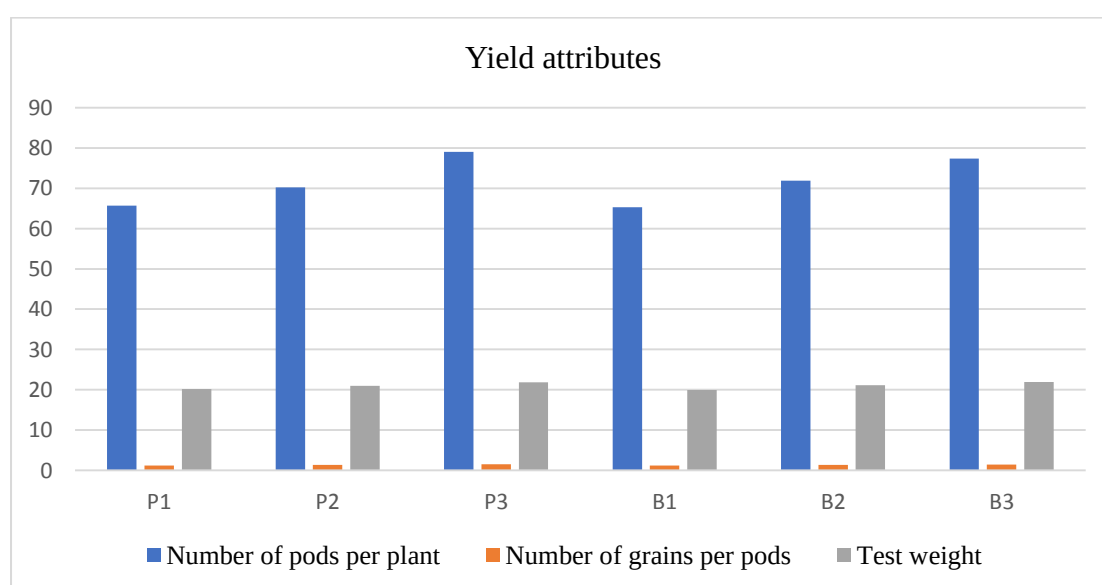
4.2.3 Test weight (g)

On the application of 60 kg P_2O_5 ha⁻¹, the higher test weight (21.84 g) was observed over 20 kg P_2O_5 ha⁻¹ (20.21 g) but found statically at par with 40 kg P_2O_5 ha⁻¹ (20.98 g).

On increasing the levels of PSB, observed increased in test weight of lentil. The maximum test weight was observed on inoculation of PSB at 10mL kg⁻¹ seed (21.92 g) which was significantly higher than 0mL PSB kg⁻¹ seed (19.99 g) and remained statically at par with 5mL PSB kg⁻¹ of seed (21.13 g).

Table 4.6: Effect of different levels of phosphorus and PSB inoculation on yield attributes of lentil under bael based agri-horti system

Treatment	Yield attributes		
	No. of pods plant ⁻¹	No. of grains pod ⁻¹	Test weight
Levels of Phosphorus (kg ha⁻¹)			
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	65.68	1.18	20.21
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	70.18	1.36	20.98
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	78.98	1.50	21.84
SEm±	1.04	0.02	0.31
CD (P= 0.05)	3.02	0.06	0.91
Levels of PSB (mL kg⁻¹)			
B ₁ (0mL PSB kg ⁻¹ seed)	65.25	1.19	19.99
B ₂ (5mL PSB kg ⁻¹ seed)	71.84	1.4	21.13
B ₃ (10mL PSB kg ⁻¹ seed)	77.37	1.46	21.92
SEm±	1.04	0.02	0.31
CD (P= 0.05)	3.02	0.06	0.89
Interaction	S	NS	NS

Fig. 4.6: Effect of different levels of phosphorus and PSB inoculation on yield attributes of lentil under bael based agri-horti system

The interaction between different levels of phosphorus and PSB inoculation on the number of pods plant⁻¹ were found significant. The data presented in table 4.6.a

Table 4.6.a: Interaction between the levels of phosphorus and PSB inoculation on the number of pods plant⁻¹ of lentil crop under bael based agri-horti system.

Treatments	Interaction effect of P and PSB on number of pods plant ⁻¹ at harvest		
	P ₁	P ₂	P ₃
	(20 kg P ₂ O ₅ ha ⁻¹)	(40 kg P ₂ O ₅ ha ⁻¹)	(60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	62.53	64.75	68.48
B ₂ (5mL PSB kg ⁻¹ seed)	66.65	70.63	78.25
B ₃ (10mL PSB kg ⁻¹ seed)	67.85	75.15	90.20
SEm±		1.79	
CD (P= 0.05)		5.24	

Under the treatment 60 kg P₂O₅ ha⁻¹ in association with 10mL PSB kg⁻¹ seed inoculation significantly increased number of pods plant⁻¹ of lentil crop (90.20 pods plant⁻¹) as compared to other treatment combinations. The second highest number of pods plant⁻¹ (78.25 pods plant⁻¹) of lentil were found on the application of 60 kg P₂O₅ ha⁻¹ along with 5mL PSB kg⁻¹ seed inoculation whereas the least number of pods plant⁻¹ (62.53 pods plant⁻¹) were noticed on the application of 20 kg P₂O₅ ha⁻¹ alone.

4.3 Yield

Data pertaining to yield which are grain yield (qha^{-1}), straw yield (qha^{-1}), biological yield (qha^{-1}) and harvest index (%) are presented in table 4.7 and depicted in fig. 4.7.

4.3.1 Grain yield (qha^{-1})

The grain yield was found significantly higher on the application of 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (12.45 qha^{-1}) over 40 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (11.17 qha^{-1}) and 20 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (9.79 qha^{-1}). All the levels of phosphorus application were found to be significantly superior with each other.

The highest grain yield was observed on inoculation with 10mL PSB kg^{-1} seed (12.02 qha^{-1}) which was found significantly superior over 0mL PSB kg^{-1} seed inoculation (9.79 qha^{-1}) but remained statically at par with 5mL PSB kg^{-1} seed inoculation (11.59 qha^{-1}).

4.3.2 Straw yield (qha^{-1})

The maximum straw yield was recorded on application of 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (16.42 qha^{-1}) which was significantly superior over 40 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (15.09 qha^{-1}) and 20 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (14.03 qha^{-1}).

On increasing the levels of PSB, there was increased in straw yield. The maximum straw yield was observed under the treatment 10mL PSB kg^{-1} seed inoculation (15.97 qha^{-1}) which was significantly superior over 0mL PSB kg^{-1} seed inoculation (14.00 qha^{-1}) but remained statically at par with 5mL PSB kg^{-1} of seed (15.57 qha^{-1}).

4.3.3 Biological yield (qha^{-1})

On the application 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$, a higher biological yield was obtained (28.87 qha^{-1}) which was significantly superior to both the lower levels which are 40 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (26.26 qha^{-1}) and 20 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ (23.82 qha^{-1}).

Increasing the level of PSB, the biological yield was increased. 10mL PSB kg^{-1} seed inoculation recorded the highest biological yield (27.99 qha^{-1}) which was significantly higher over 5mL PSB kg^{-1} seed inoculation (27.16 qha^{-1}) and 0mL PSB kg^{-1} seed inoculation (23.79 qha^{-1}).

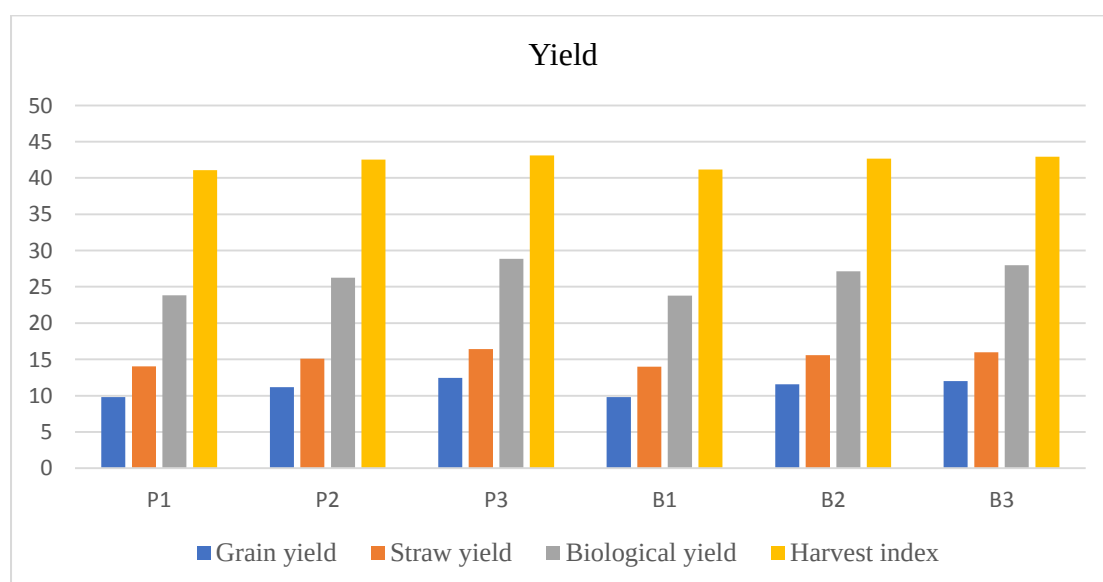
4.3.4 Harvest Index (%)

The maximum value for harvest index was found on application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (43.12%) followed by $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (42.53%) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (41.09%) respectively. All the levels of phosphorus application were found to be non-significant with each other.

In case of PSB, the maximum value for harvest index (42.94%) was observed on seed inoculation with 10mL PSB kg^{-1} seed inoculation followed by 5mL PSB kg^{-1} seed inoculation (42.67%) and 0mL PSB kg^{-1} seed inoculation (41.15%). All the levels of PSB inoculation were found to be non-significant with each other.

Table 4.7: Effect of different levels of phosphorus and PSB inoculation on yield of lentil under bael based agri-horti system

Treatment	Yield			
	Grain yield (qha ⁻¹)	Straw yield (qha ⁻¹)	Biological yield (qha ⁻¹)	Harvesting index (%)
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	9.79	14.03	23.82	41.09
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	11.17	15.09	26.26	42.53
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	12.45	16.42	28.87	43.12
SEm±	0.16	0.22	0.25	-
CD (P= 0.05)	0.46	0.64	0.72	NS
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	9.79	14.00	23.79	41.15
B ₂ (5mL PSB kg ⁻¹ seed)	11.59	15.57	27.16	42.67
B ₃ (10mL PSB kg ⁻¹ seed)	12.02	15.97	27.99	42.94
SEm±	0.16	0.22	0.25	-
CD (P= 0.05)	0.46	0.64	0.72	NS
Interaction	S	NS	NS	-

Fig 4.7: Effect of different levels of phosphorus and PSB inoculation on yield of lentil under bael based agri-horti system

The interaction between different levels of phosphorus and PSB on grain yield was found significant. The data presented in table 4.7.a.

Table 4.7.a: Interaction between different levels of phosphorus and PSB inoculation on grain yield of lentil crop at harvest

Treatments	Interaction effect of P and PSB on grain yield		
	P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	P ₃ (60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	9.24	9.72	10.42
B ₂ (5mL PSB kg ⁻¹ seed)	9.99	11.72	13.07
B ₃ (10mL PSB kg ⁻¹ seed)	10.13	12.07	13.88
SEm±		0.28	
CD (P= 0.05)		0.81	

On association of 60 kg P₂O₅ ha⁻¹ with 10mL PSB kg⁻¹ seed inoculation significantly increased the grain yield of lentil crop (13.88 qha⁻¹) as compared to other treatment combinations. The least value of grain yield (9.24 qha⁻¹) was recorded under treatment 0mL PSB kg⁻¹ seed inoculation and 20 kg P₂O₅ ha⁻¹ phosphorus application.

4.4 Nutrient studies

4.4.1 Nitrogen content (%) and its uptake (kg ha^{-1}) by crop

Data regarding nitrogen content and uptake is presented in table 4.8 and shown in fig. 4.8.

4.4.1.1 Nitrogen content in grain (%)

On increasing the levels of phosphorus fertilizer and PSB increases the nitrogen content in grain. The maximum nitrogen content in grain was observed on the application of phosphorus at $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.53%) which was significantly superior over $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.26%) but remained statically at par with $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.42%).

Similarly, on seed inoculation of lentil with 10mL PSB kg^{-1} seed observed the maximum nitrogen content in grain (3.5%) which was significantly superior over no inoculation (3.26%) and found statically at par with 5mL PSB kg^{-1} seed inoculation (3.45%).

4.4.1.2 Nitrogen content in straw (%)

With respect to nitrogen content in straw, it was observed that on the application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ recorded higher nitrogen content in straw (0.63%) which founds significantly higher over $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.58%) but remains statically at par with $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.61%).

The maximum nitrogen content in straw was observed on seed inoculation with 10mL PSB kg^{-1} seed (0.63%) which was significantly higher than 0mL PSB kg^{-1} seed (0.59%) but remained statically at par with 5mL PSB kg^{-1} of seed (0.61%).

4.4.1.3 Nitrogen uptake in grain (kg ha^{-1})

Nitrogen uptake in grains was enhanced on increasing levels of phosphorus. The maximum nitrogen uptake in grain was observed on the application of $60 \text{ kg P}_2\text{O}_5$

ha⁻¹ (44.22 kg ha⁻¹) followed by 40 kg P₂O₅ ha⁻¹ (38.26 kg ha⁻¹) whereas the minimum nitrogen uptake in grain was observed on the application of 20 kg P₂O₅ ha⁻¹ (32.01 kg ha⁻¹).

On application of 10mL PSB kg⁻¹ seed recorded the maximum nitrogen uptake in grain (42.33 kg ha⁻¹) which was significantly superior over 0mL PSB kg⁻¹ seed inoculation (32.05 kg ha⁻¹) but remained statically at par with 5mL PSB kg⁻¹ seed inoculation (40.12 kg ha⁻¹).

4.4.1.4 Nitrogen uptake in straw (kg ha⁻¹)

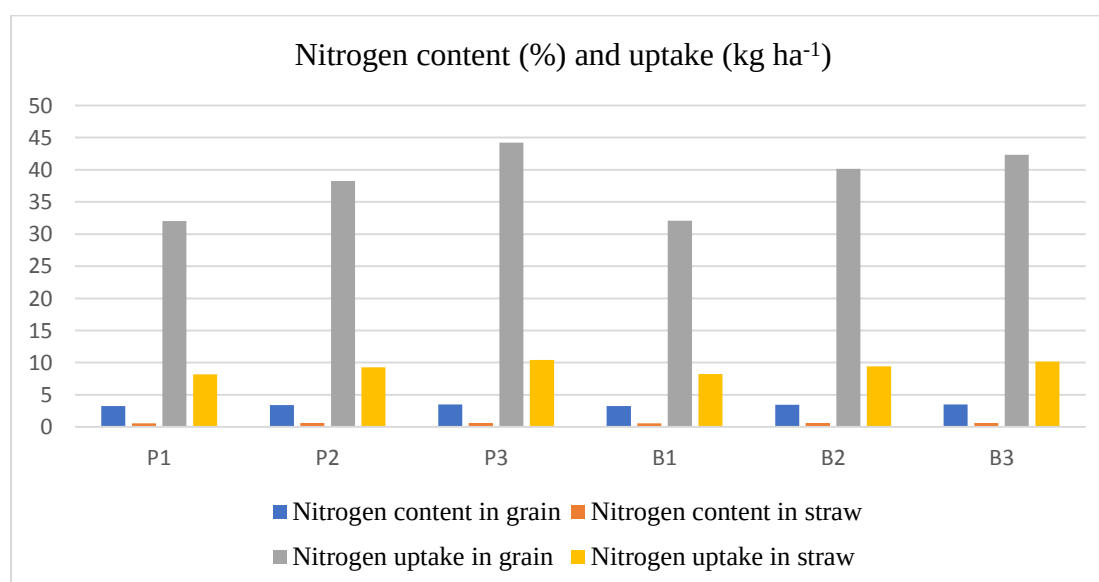
The highest amount of nitrogen uptake in straw (10.4 kg ha⁻¹) was found on the application of 60 kg P₂O₅ ha⁻¹ which was significantly superior over both the lower levels which are 40 kg P₂O₅ ha⁻¹ (9.28 kg ha⁻¹) and 20 kg P₂O₅ ha⁻¹ (8.17 kg ha⁻¹).

Similarly, the maximum nitrogen uptake in straw was observed on application of 10mL PSB kg⁻¹ seed inoculation (10.15 kg ha⁻¹) which was significantly superior over 5mL PSB kg⁻¹ seed (9.45 kg ha⁻¹) and with 0mL PSB kg⁻¹ seed (8.24 kg ha⁻¹).

Table 4.8: Effect of different levels of phosphorus and PSB inoculation on nitrogen content in grain and straw and their uptake by lentil under bael based agri-horti system

Treatment	N content (%)		N uptake (kg ha ⁻¹)	
	Grain	Straw	Grain	Straw
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	3.26	0.58	32.01	8.17
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	3.42	0.61	38.26	9.28
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	3.53	0.63	44.22	10.4
SEm±	0.05	0.01	0.94	0.21
CD (P= 0.05)	0.14	0.03	2.75	0.61
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	3.26	0.59	32.05	8.24
B ₂ (5mL PSB kg ⁻¹ seed)	3.45	0.61	40.12	9.45
B ₃ (10mL PSB kg ⁻¹ seed)	3.5	0.63	42.33	10.15
SEm±	0.05	0.01	0.94	0.21
CD (P= 0.05)	0.14	0.03	2.75	0.61
Interaction	NS	NS	NS	NS

Fig. 4.8: Effect of different levels of phosphorus and PSB inoculation on nitrogen content in grain and straw and their uptake by lentil under bael based agri-horti system



4.4.2 Phosphorus content (%) and its uptake (kg ha^{-1}) by crop

Data regarding phosphorus content and uptake is presented in table 4.9 and shown in fig 4.9.

4.4.2.1 Phosphorus content in grain (%)

Phosphorus content in grain was increased on increasing the phosphorus levels. The maximum phosphorus content in grain (0.42%) was observed on the application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ which was significantly superior over $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.35%) but found statistically comparable with $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.39%).

On application of PSB at 10 mL kg^{-1} seed recorded the maximum phosphorus content in grain (0.43%) which was significantly superior over 0 mL PSB kg^{-1} seed inoculation (0.32%) but remained statically at par with 5 mL PSB kg^{-1} seed (0.42%).

4.4.2.2 Phosphorus content in straw (%)

The phosphorus content in straw was increased on increasing phosphorus levels where $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.28%) recorded the highest phosphorus content in straw which was significantly superior to $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.25%) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (0.22%).

The phosphorus content in the straw was observed highest on seed inoculation with PSB at $10 \text{ mL PSB kg}^{-1}$ seed (0.27%) which was significantly higher over 0 mL PSB kg^{-1} seed (0.22%) and remained statically at par with 5 mL PSB kg^{-1} seed inoculation (0.26%).

4.4.2.3 Phosphorus uptake in grain (kg ha^{-1})

Application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ was recorded with the maximum phosphorus uptake in grain (5.3 kg ha^{-1}) followed by $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (4.4 kg ha^{-1}) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.46 kg ha^{-1}).

PSB inoculation of seed with 10mL PSB kg⁻¹ seed (5.16 kg ha⁻¹) obtained the maximum phosphorus uptake in grain which was significantly higher over 0mL PSB kg⁻¹ seed (3.13 kg ha⁻¹) but remained statically at par with 5mL PSB kg⁻¹ seed (4.87 kg ha⁻¹).

4.4.2.4 Phosphorus uptake in straw (kg ha⁻¹)

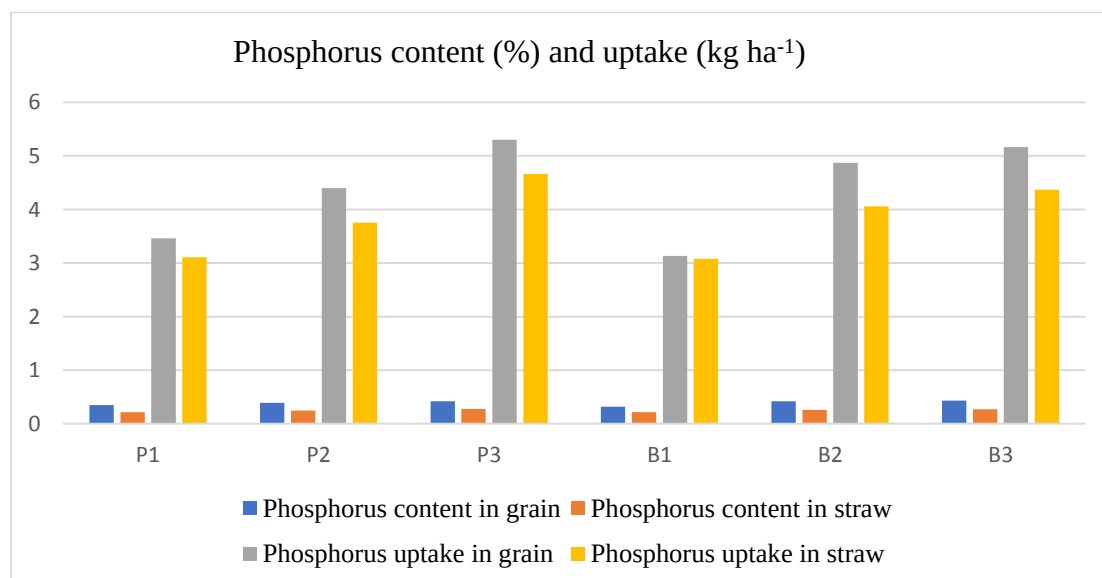
The highest amount of phosphorus uptake in straw was recorded on the application of 60 kg P₂O₅ ha⁻¹ (4.66 kg ha⁻¹) which founds significantly superior over 40 kg P₂O₅ ha⁻¹ (3.75 kg ha⁻¹) and 20 kg P₂O₅ ha⁻¹ (3.11 kg ha⁻¹).

The maximum amount of phosphorus uptake in straw was observed with seed inoculation at 10mL PSB kg⁻¹ seed (4.37 kg ha⁻¹) which was significantly higher than 5mL PSB kg⁻¹ seed (4.06 kg ha⁻¹) and 0mL PSB kg⁻¹ seed inoculation (3.08 kg ha⁻¹).

Table 4.9: Effect of different levels of phosphorus and PSB inoculation on phosphorus content in grain and straw and their uptake by lentil under bael based agri-horti system

Treatment	P content (%)		P uptake (kg ha ⁻¹)	
	Grain	Straw	Grain	Straw
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	0.35	0.22	3.46	3.11
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	0.39	0.25	4.4	3.75
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	0.42	0.28	5.3	4.66
SEm±	0.01	0.01	0.1	0.1
CD (P= 0.05)	0.03	0.02	0.3	0.28
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	0.32	0.22	3.13	3.08
B ₂ (5mL PSB kg ⁻¹ seed)	0.42	0.26	4.87	4.06
B ₃ (10mL PSB kg ⁻¹ seed)	0.43	0.27	5.16	4.37
SEm±	0.01	0.01	0.1	0.1
CD (P= 0.05)	0.03	0.02	0.3	0.28
Interaction	NS	NS	NS	NS

Fig 4.9: Effect of different levels of phosphorus and PSB inoculation on phosphorus content in grain and straw and their uptake by lentil under bael based agri-horti system



4.4.3 Potassium content (%) and its uptake (kg ha^{-1}) by crop

Data concerning potassium content and uptake is presented in table 4.10 and shown in fig. 4.10.

4.4.3.1 Potassium content in grain (%)

The highest potassium content in grain was observed under treatment $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (1.26%) which remained statically at par with $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (1.21%). The minimum phosphorus content in grain was recorded under treatment $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (1.16%).

Potassium content in grain was recorded maximum under treatment $10 \text{ mL PSB kg}^{-1}$ seed (1.26%) which was significantly superior over 0 mL PSB kg^{-1} seed application (1.14%) but remained statically at par with 5 mL PSB kg^{-1} seed inoculation (1.23%).

4.4.3.2 Potassium content in straw (%)

The maximum potassium content in straw was noted on the application of phosphorus at $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.45%) which was higher than both the lower levels which was $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.39%) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (3.32%).

On seed inoculation with PSB at 10 mL kg^{-1} seed recorded the highest potassium content in straw (3.43%) which was significantly higher than seed inoculation with 0 mL PSB kg^{-1} seed (3.33%) but remained statically at par with 5 mL PSB kg^{-1} seed inoculation (3.40%).

4.4.3.3 Potassium uptake in grain (kg ha^{-1})

The highest amount of potassium uptake in grain was noted on the application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (15.69 kg ha^{-1}) followed by $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (13.62 kg ha^{-1}) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (11.31 kg ha^{-1}).

10mL PSB kg⁻¹ seed had significantly higher potassium uptake in grain (15.06 kg ha⁻¹) than 5mL PSB kg⁻¹ seed (14.35 kg ha⁻¹) and 0mL PSB kg⁻¹ seed inoculation (11.22 kg ha⁻¹).

4.4.3.4 Potassium uptake in straw (kg ha⁻¹)

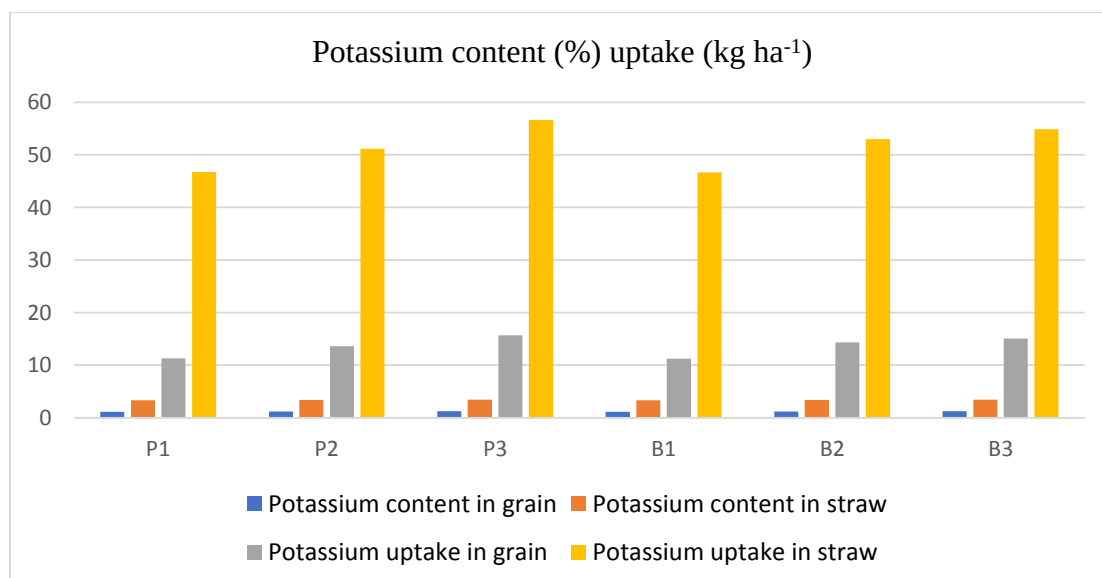
The maximum potassium uptake in straw was observed on the application of phosphorus at 60 kg P₂O₅ ha⁻¹ (56.62 kg ha⁻¹) followed by 40 kg P₂O₅ ha⁻¹ (51.14 kg ha⁻¹) and 20 kg P₂O₅ ha⁻¹ (46.74 kg ha⁻¹).

Seed inoculation with 10mL PSB kg⁻¹ seed (54.86 kg ha⁻¹) had significantly higher potassium uptake in straw over 0mL PSB kg⁻¹ seed (46.67 kg ha⁻¹) but found statically at par with 5mL PSB kg⁻¹ seed (52.97 kg ha⁻¹).

Table 4.10: Effect of different levels of phosphorus and PSB inoculation on potassium content in the grain and straw and their uptake by lentil under bael based agri-horti system

Treatment	K content (%)		K uptake (kg ha ⁻¹)	
	Grain	Straw	Grain	Straw
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	1.16	3.32	11.31	46.74
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	1.21	3.39	13.62	51.14
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	1.26	3.45	15.69	56.62
SEm±	0.02	0.02	0.18	0.86
CD (P= 0.05)	0.05	0.06	0.54	2.51
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	1.14	3.33	11.22	46.67
B ₂ (5mL PSB kg ⁻¹ seed)	1.23	3.4	14.35	52.97
B ₃ (10mL PSB kg ⁻¹ seed)	1.26	3.43	15.06	54.86
SEm±	0.02	0.02	0.18	0.86
CD (P= 0.05)	0.05	0.06	0.54	2.51
Interaction	NS	NS	NS	NS

Fig. 4.10: Effect of different levels of phosphorus and PSB inoculation on potassium content in grain and straw and their uptake by lentil under bael based agri-horti system



4.5 Qualitative attributes

In qualitative attributes, protein content and uptake in grain and straw of lentil were determined and the data is presented in table 4.11 and fig. 4.11.

4.5.1 Protein content in grain (%)

Under the treatment of phosphorus 60 kg P_2O_5 ha⁻¹ resulted in the highest protein content in grain (22.08%), which founds significantly higher over 20 kg P_2O_5 ha⁻¹ (20.37%) but statistically comparable to 40 kg P_2O_5 ha⁻¹ (21.34%).

In terms of PSB inoculation, the highest protein content (22.7%) was reported with 10mL PSB kg⁻¹ seed inoculation, which was substantially higher than uninoculated with PSB (21.31%) but found statistically at par to 5mL PSB kg⁻¹ seed inoculation (22.32%).

4.5.2 Protein content in straw (%)

The highest level of protein content in straw was observed under the treatment 60 kg P_2O_5 ha⁻¹ (3.95%) which was significantly superior over 20 kg P_2O_5 ha⁻¹ (3.63%) but remained statically at par with 40 kg P_2O_5 ha⁻¹ (3.83%).

The highest level of protein content in straw was detected on the application of 10mL PSB kg⁻¹ seed (3.95%) which was found superior over both the lower levels which are 5mL (3.79%) and 0mL (3.67%) PSB kg⁻¹ seed inoculation.

4.5.3 Protein uptake in grain (kg ha⁻¹)

Phosphorus at 60 kg P_2O_5 ha⁻¹ had recorded better protein uptake in grain (276.4 kg ha⁻¹) than 40 kg P_2O_5 ha⁻¹ (239.14 kg ha⁻¹) and 20 kg P_2O_5 ha⁻¹ (200.09 kg ha⁻¹).

Protein uptake in grain was significantly higher on seed inoculation with 10mL PSB kg⁻¹ seed (316.6 kg ha⁻¹) than 5mL PSB kg⁻¹ seed (290.68 kg ha⁻¹) and 0mL PSB kg⁻¹ seed inoculation (221.93 kg ha⁻¹).

4.5.4 Protein uptake in straw (kg ha^{-1})

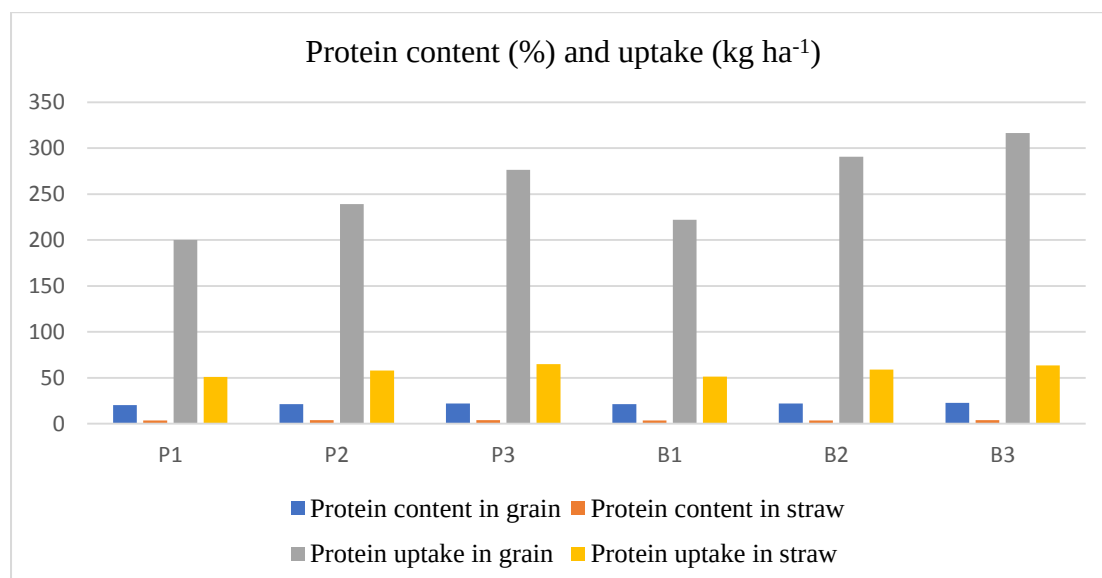
With the application of $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (64.98 kg ha^{-1}) shows significantly higher protein uptake in straw than $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (57.98 kg ha^{-1}) and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ (51.05 kg ha^{-1}).

Protein uptake in straw was significantly higher with 10mL PSB kg^{-1} seed inoculation (63.44 kg ha^{-1}) than 5mL PSB kg^{-1} seed inoculation (59.09 kg ha^{-1}) and control (51.48 kg ha^{-1}).

Table 4.11: Effect of different levels of phosphorus and PSB inoculation on protein content in grain and straw and their uptake by lentil under bael based agri-horti system

Treatment	Protein (%)		Protein yield (kg ha ⁻¹)	
	Grain	Straw	Grain	Straw
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	20.37	3.63	200.09	51.05
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	21.34	3.83	239.14	57.98
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	22.08	3.95	276.4	64.98
SEm±	0.3	0.05	5.89	1.31
CD (P= 0.05)	0.87	0.16	17.18	3.84
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	21.31	3.67	221.93	51.48
B ₂ (5mL PSB kg ⁻¹ seed)	22.23	3.79	290.68	59.09
B ₃ (10mL PSB kg ⁻¹ seed)	22.7	3.95	316.6	63.44
SEm±	0.3	0.05	5.89	1.31
CD (P= 0.05)	0.87	0.16	17.18	3.84
Interaction	NS	NS	NS	NS

Fig. 4.11: Effect of different levels of phosphorus and PSB inoculation on protein content in grain and straw and their uptake by lentil under bael based agri-horti system



4.6 Economics

Table 4.12 and fig. 4.12 contain information on the economics of various treatments on lentil.

4.6.1 Total cost of cultivation (₹ ha⁻¹)

Because of increasing the phosphorus levels, the cost of cultivation of lentil had increased. The application of phosphorus 60 kg P₂O₅ ha⁻¹ had the greatest cost of cultivation (29175.43 ₹ ha⁻¹) followed by 40 kg P₂O₅ ha⁻¹ (28189.32 ₹ ha⁻¹) and 20 kg P₂O₅ ha⁻¹ (27251.81 ₹ ha⁻¹).

Similarly, when the levels of PSB inoculation was increased, the cost of cultivation was increased, where the highest cost of cultivation was observed on application of 10mL PSB kg⁻¹ seed inoculation (28282.56 ₹ ha⁻¹) followed by 5mL PSB kg⁻¹ seed inoculation (28205.52 ₹ ha⁻¹) and 0mL PSB kg⁻¹ seed inoculation (28128.47 ₹ ha⁻¹).

4.6.2 Gross returns (₹ ha⁻¹)

The application of phosphorus at a rate of 60 kg P₂O₅ ha⁻¹ showed the best gross returns (63059.33 ₹ ha⁻¹), significantly higher over 40 kg P₂O₅ ha⁻¹ (56621.83 ₹ ha⁻¹), and 20 kg P₂O₅ ha⁻¹ (49774.50 ₹ ha⁻¹).

Similarly, on increasing the doses of PSB inoculation boosted gross yields significantly, with the maximum gross return was observed with 10mL PSB kg⁻¹ seed inoculation (60906.83 ₹ ha⁻¹), which was significantly better than 0mL PSB kg⁻¹ seed inoculation (49787.17 ₹ ha⁻¹) but statistically comparable to 5mL PSB kg⁻¹ inoculation (58761.67 ₹ ha⁻¹).

4.6.3 Net returns (₹ ha⁻¹)

The highest net return was obtained on application of 60 kg P₂O₅ ha⁻¹ (33883.90 ₹ ha⁻¹) followed by 40 kg P₂O₅ ha⁻¹ (28432.51 ₹ ha⁻¹) and 20 kg P₂O₅ ha⁻¹ (22522.69 ₹ ha⁻¹).

The maximum net returns (32624.27 ₹ ha⁻¹) were obtained on seed inoculation with 10mL PSB kg⁻¹ seed, which was significantly better than 0mL PSB kg⁻¹ seed (21658.70 ₹ ha⁻¹) but found statistically at par with 5mL PSB kg⁻¹ seed inoculation (30556.15 ₹ ha⁻¹).

4.6.6 Benefit-Cost ratio

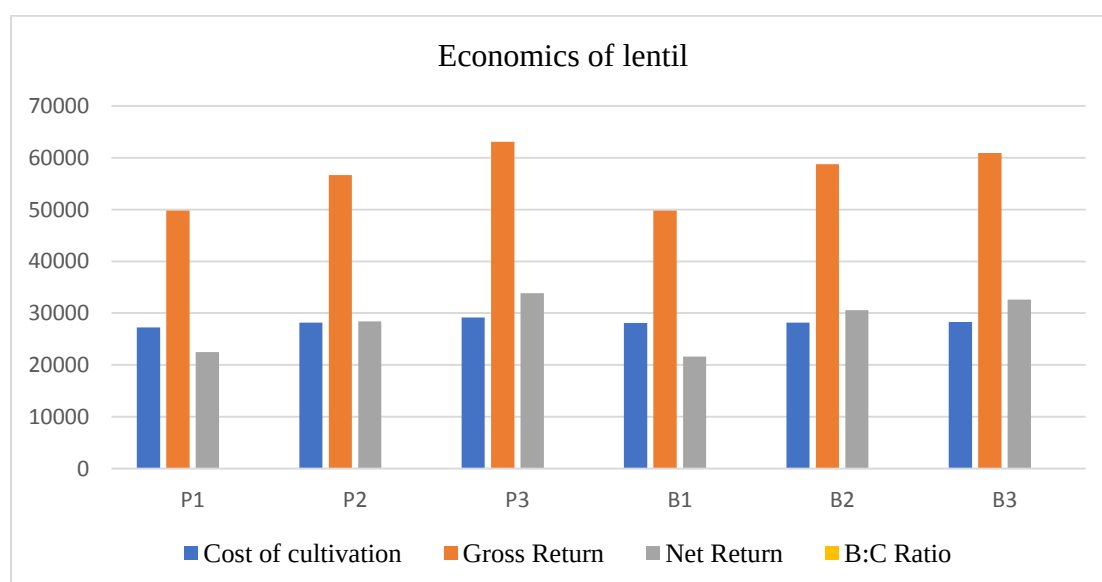
Phosphorus at a rate of 60 kg P₂O₅ ha⁻¹ recorded the maximum benefit-cost ratio (1.16) followed by 40 kg P₂O₅ ha⁻¹ (1.01) and 20 kg P₂O₅ ha⁻¹ (0.83).

In the case of PSB inoculation, the maximum benefit-cost ratio (1.15) was obtained with 10mL PSB kg⁻¹ seed inoculation, which was considerably better than 0mL PSB kg⁻¹ seed (0.77) but statistically comparable to 5mL PSB kg⁻¹ seed inoculation (1.08).

Table 4.12: Economics of lentil as influenced by the levels of phosphorus and PSB inoculation under bael based agri-horti system

Treatment	Economics			
	Cost of cultivation (₹ ha ⁻¹)	Gross Return (₹ ha ⁻¹)	Net Return (₹ ha ⁻¹)	B:C Ratio
Levels of Phosphorus (kg ha⁻¹)				
P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	27251.81	49774.50	22522.69	0.83
P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	28189.32	56621.83	28432.51	1.01
P ₃ (60 kg P ₂ O ₅ ha ⁻¹)	29175.43	63059.33	33883.90	1.16
SEm±		757.36	757.36	0.03
CD (P= 0.05)		2210.57	2210.57	0.08
Levels of PSB (mL kg⁻¹)				
B ₁ (0mL PSB kg ⁻¹ seed)	28128.47	49787.17	21658.70	0.77
B ₂ (5mL PSB kg ⁻¹ seed)	28205.52	58761.67	30556.15	1.08
B ₃ (10mL PSB kg ⁻¹ seed)	28282.56	60906.83	32624.27	1.15
SEm±		757.36	757.36	0.03
CD (P= 0.05)		2210.57	2210.57	0.08
Interaction		S	S	NS

*Rate of lentil grain (₹ kg⁻¹) = 48 ₹ kg⁻¹, *Rate of lentil straw (₹ kg⁻¹) = 2.00 ₹ kg⁻¹

Fig. 4.12: Economics of lentil as influenced by the levels of Phosphorus and PSB inoculation under bael based agri-horti system

In lentil, the interaction between different phosphorus and PSB inoculation with respect to the gross returns was found significant.

Table 4.12a: Interaction between the different levels of phosphorus and PSB inoculation on gross return (₹ ha⁻¹) of lentil crop at harvest

Treatments	Interaction effect of P and PSB on gross return		
	P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	P ₃ (60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	46940.00	49405.50	53016.00
B ₂ (5mL PSB kg ⁻¹ seed)	50805.50	59380.00	66099.50
B ₃ (10mL PSB kg ⁻¹ seed)	51578.00	61080.00	70062.50
SEm±		1131.78	
CD (P= 0.05)		3828.82	

The maximum gross return was observed under treatment 60 kg P₂O₅ ha⁻¹ with 10mL PSB kg⁻¹ seed (70062.50 ₹ ha⁻¹) followed by 60 kg P₂O₅ ha⁻¹ with combine application with 5 mL PSB kg⁻¹ seed (66099.50 ₹ ha⁻¹). The least gross return of lentil was obtained on application of phosphorous alone at 20 kg P₂O₅ ha⁻¹ (46940.0 ₹ ha⁻¹).

In lentil, the interaction between phosphorus levels and PSB inoculation with respect to net returns was found significant.

Table 4.12b: Interaction between different levels of phosphorus and PSB inoculation on net return (₹ ha⁻¹) of lentil crop at harvest

Treatments	Interaction effect of P and PSB on net return		
	P ₁ (20 kg P ₂ O ₅ ha ⁻¹)	P ₂ (40 kg P ₂ O ₅ ha ⁻¹)	P ₃ (60 kg P ₂ O ₅ ha ⁻¹)
B ₁ (0mL PSB kg ⁻¹ seed)	19765.23	21293.22	23917.64
B ₂ (5mL PSB kg ⁻¹ seed)	23553.69	31190.68	36924.06
B ₃ (10mL PSB kg ⁻¹ seed)	24249.15	32813.64	40810.02
SEm±		1311.78	
CD (P= 0.05)		3828.82	

The maximum net return was observed on application of 60 kg P₂O₅ ha⁻¹ along with 10mL PSB kg⁻¹ seed inoculation (40810.02 ₹ ha⁻¹) followed by 60 kg P₂O₅ ha⁻¹ with 5mL PSB kg⁻¹ seed inoculation (36924.06 ₹ ha⁻¹). Least gross return of lentil was obtained on application of phosphorous alone at 20 kg P₂O₅ ha⁻¹ (19765.23 ₹ ha⁻¹).

4.7 Observations of the bael fruit tree

4.7.1 Growth parameter of bael tree

4.7.1.1 Tree height (m)

Three trees were taken as sample from each replication. The height of the sample trees was recorded and the average was estimated. Tree height was measured from the base of the tree up to the tip. An average height recorded was 7.9 m.

	Replication I	Replication II	Replication III	Replication IV	Average
Tree height (m)	8	8.2	7.4	8.1	7.9

4.7.1.2 Canopy (m)

The canopy area of the sample trees was recorded with the help of meter tape and the average was estimated. An average plant canopy recorded is 4.7 m

	Replication I	Replication II	Replication III	Replication IV	Average
Canopy Spread (m)	4.9	5	4.3	4.7	4.7

4.7.1.3 Stem girth (cm).

The stem girth of tree was recorded with the help of Vernier caliper. Two diameters were taken at right angle to each other at diameter breast height and the average was taken. An average stem girth recorded is 57.4 cm.

	Replication I	Replication II	Replication III	Replication IV	Average
Girth (cm)	57.7	60.9	54.8	56.5	57.4

4.7.1.4 Shading (m)

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

Shading area (m)							
Replication I		Replication II		Replication III		Replication IV	
Length	Width	Length	Width	Length	Width	Length	Width
4	3.42	4.13	3.45	3.9	3.2	3.8	3.4

4.7.2 Yield parameters and yield (kg ha^{-1}) of bael

The number of fruits ha^{-1} , an average number of fruits tree $^{-1}$, average weight of fruit and average fruit yield (kg ha^{-1}) were recorded and the relevant data are presented in the table 4.13

The total number of bael trees in one hectare are 204 trees. An average numbers of fruits per tree were 40 fruits tree $^{-1}$ and an average weight of each fruit is 500 g. On an average 4080 kg fruits hectare $^{-1}$ was obtained.

4.7.3 Economic return from tree component

The data regarding the economics of the bael tree is presented in table 4.15 and depicted in fig. 4.15.

The gross return (77520 ₹ ha^{-1}) is obtained by multiplying the average yield of fruit tree hectare $^{-1}$ (4080 kg ha^{-1}) with current market rate of fruit (19 ₹ kg^{-1}). The net return and B:C ratio of fruit trees were (Rs 57869.5 ₹ ha^{-1}) and (2.94) respectively.

Table 4.13: Yield attributes, yield and economic of bael fruit trees under agri-horti system in cropping period

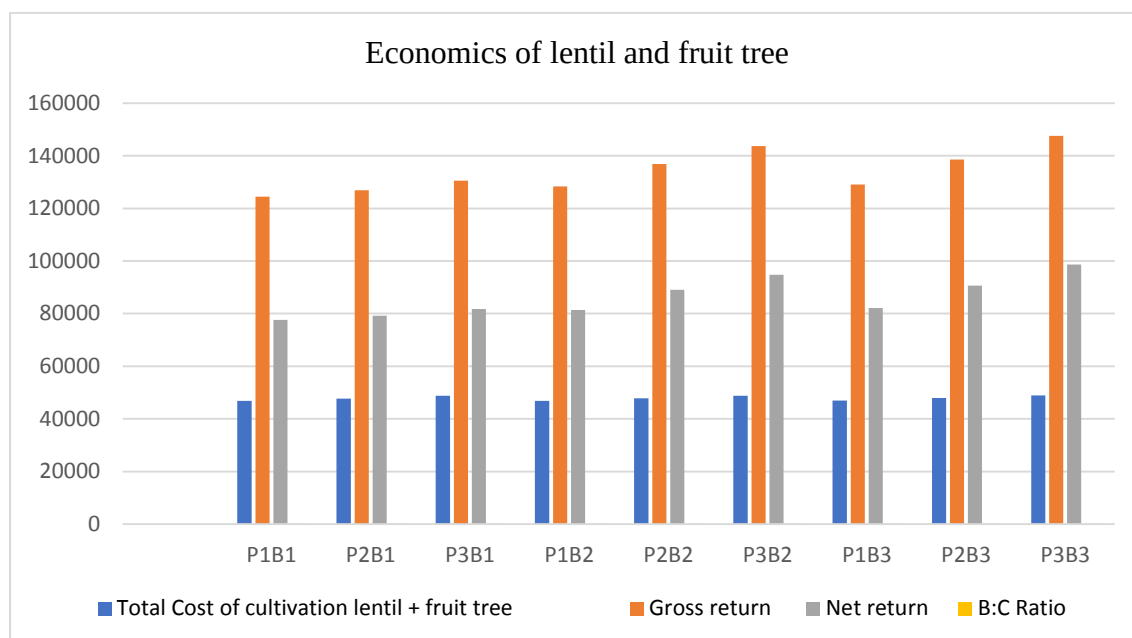
Fruit tree	Average no. of fruits tree (ha⁻¹)	Average no. of fruit tree⁻¹	Average weight of fruit (g)	Fruit yield (kg ha⁻¹)	Rate of fruit (₹ kg⁻¹)	Gross return from fruit (₹ ha⁻¹)
Bael	204	40	500	4080	19	77520

Table 4.14: Economics of bael fruit under agri-horti system

Cost of cultivation (₹ ha⁻¹)	Gross return (₹ ha⁻¹)	Net return (₹ ha⁻¹)	B:C ratio
19650.5	77520	57869.5	2.94

Table 4.15: Treatments wise economics of lentil and fruit tree under bael based agri-horti system.

Treatment	Total Cost of cultivation lentil + fruit tree (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)			Net return (₹ ha ⁻¹)	B:C Ratio
		Lentil return	Fruit tree return	Total		
P ₁ B ₁	46825.27	46940.00	77520.00	124460.00	77634.73	1.66
P ₂ B ₁	47762.78	49405.50	77520.00	126925.50	79162.72	1.66
P ₃ B ₁	48748.86	53016.00	77520.00	130536.00	81787.14	1.68
P ₁ B ₂	46902.31	50805.50	77520.00	128325.50	81423.19	1.74
P ₂ B ₂	47839.82	59380.00	77520.00	136900.00	89060.18	1.86
P ₃ B ₂	48825.94	66099.50	77520.00	143619.50	94793.56	1.94
P ₁ B ₃	46979.35	51578.00	77520.00	129098.00	82118.6	1.75
P ₂ B ₃	47916.86	61080.00	77520.00	138600.00	90683.14	1.89
P ₃ B ₃	48902.98	70062.50	77520.00	147582.5	98679.52	2.02

Fig 4.13: Treatments wise economics of lentil and fruit tree under bael based agri-horti system.

DISCUSSION

The investigation took place in the Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, during the winter (Rabi) season of 2019. In the preceding chapter, the results of the experimentation **“Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system”** were detailed. In this chapter, an attempt is made to evaluate the major findings made during the experiment in terms of cause, substantial effect, and relationship with the crop as a result of the combination of different treatments. The yield unit⁻¹ area is determined by the yield obtained from each plant. Yield plant⁻¹ is determined by the growth parameters and yield traits of the plant. These factors are influenced by physiological and metabolic processes which are influenced by environmental factors, fertilizer application, and other agronomic managements.

5.1 Effect of weather

The outcomes of the field experiment were influenced by the weather conditions in the area. The weather relationship with the crop must be taken into account for accurate interpretation and conclusion; otherwise, the discussion of the results would be improper. Table 3.1 shows the weather components, such as temperature, rainfall, and relative humidity were recorded during the cropping period of the current field experiment. Diversification in the weather component had an impact on the crop's growth, development, and yield. For the best production, each crop has its cardinal point of temperature and relative humidity. Change in the optimum climatic condition required by the plant results in crop stress which causes loss in growth, development and yield of the crop.

For healthy growth and development, all crops require a precise set of environmental conditions. Rainfall and temperature have been shown to have a significant impact on the vegetative and reproductive phases of plants. Under ideal moisture levels, lentil plants flourish. During the crop season, lentil require a temperature range of 18 to 30 degrees Celsius. Although, the plants can withstand temperatures as low as 5°C and as high as 35°C. It is drought hardy and thrives in areas with annual rainfall ranging from 650 to 850 millimeters. It demands high temperatures, low humidity, and somewhat dry weather during the maturation stage. During the cropping season, the weekly mean maximum temperature was 30°C, which was within the ideal range, while the lowest temperature 4.2°C which was lower than the optimum level (Table 3.1). The rainfall obtained throughout the trial was minimal but evenly distributed and dry weather during the maturity period aided yield metrics and thus increases crop production.

5.2 Effect of levels of phosphorus

5.2.1 Effect of levels of phosphorus application on growth parameters

Result of the experiment revealed that different levels of phosphorous had very significant impact on growth and yield of lentil. Various growth parameters such as plant height, number of branches plant⁻¹, number of green leaves plant⁻¹, number of root nodules plant⁻¹, and dry matter accumulation plant⁻¹ were influenced by the different levels of phosphorous.

It has been observed that there was a vigorous increase in plant height during the interval of 30 to 60 DAS and slow vegetative growth has been observed during 90 DAS up to harvest. On application of 60 kg P₂O₅ ha⁻¹ recorded a higher number of root nodules plant⁻¹ at 60 DAS. This might be due to higher availability of phosphorus as phosphorus plays an important role in use of sugar and starch, nucleus formation, cell division, photosynthesis and root growth that improves nodulation. Similar results have been observed by Patel *et. al* (2018). The higher level of phosphorus application i.e., 60 kg P₂O₅ ha⁻¹ observed higher plant height at a various interval of crop growth.

Parallel results were also observed with dry matter accumulation plant^{-1} where higher amount of dry matter accumulation plant^{-1} was observed on the application of higher level of phosphorous $60 \text{ P}_2\text{O}_5 \text{ ha}^{-1}$. This might be due to more number of root nodules present fixing more nitrogen in the plant roots which enhances vegetative growth of the crop. Similar results have also been shown by Zeidan (2007), Singh *et al.* (2017), Dwivedi *et al.* (2018). Increase in the plant height on increasing phosphorus levels was reported by Fatema *et al.* (2013)

5.2.2 Effect of levels of phosphorus application on yield attributes and yield

As noticed in the earlier chapters, on increasing the levels of phosphorous, yield and yield attributing parameters which are the number of pods plant^{-1} , number of grains pod^{-1} , test weight, grain yield, straw yield, biological yield and harvest index increases from $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ to $60 \text{ P}_2\text{O}_5 \text{ ha}^{-1}$. Due to tall height and a greater number of branches plant^{-1} on the application of higher level of phosphorous, resulted in a greater number of pods plant^{-1} . The number of root nodules boosted on a higher level of phosphorous application; plant reaches maximum nodules at the flowering stage where plant needs nitrogen in the maximum amount. The higher level of phosphorus induces early flowering due to increase in nitrogenase activity of root nodules. This might be the reason for more flowering and ultimately development of a greater number of pods plant^{-1} . The greater number of pods plant^{-1} resulted in higher amount of grains plant^{-1} and enhances the productivity unit⁻¹ area. The higher availability of phosphorous at higher fertility levels is likely to induce greater translocation of photosynthesis from leaves to sink that is grains. It might be the cause of higher test weight and more yield of lentil with a higher level of phosphorus. The positive response of lentil to phosphorus application reported by Sharar *et al.* (2003), Togay *et al.* (2008), Datta *et al.* (2013), Rasool *et al.* (2016), Ali *et al.* (2017).

5.2.3 Effect of levels of phosphorus application on nutrients content and uptake

Tables 4.8 to 4.10 represented the nitrogen, phosphorus and potassium content and uptake by the crop which shows that nutrient content was increased significantly

on raising the levels of phosphorus. Phosphorus application increased nutrient availability in soil, resulting in the higher uptake of nutrients, which may have increased photosynthesis and translocation of assimilates to different parts of the plant, resulting in increased crop growth and yield. More assimilates are produced in later stages that are used in growth and development, and the excess assimilates are diverted to storage compounds, increasing nitrogen, phosphorus and potassium content in grain and straw. Higher assimilation of phosphorus in seed and straw might be due to higher application of phosphorus which translocate phosphorus from roots to sink parts of plants. The same results have been found by Biswas *et al.* (2015), Singh *et al.* (2017).

5.2.4 Effect of levels of phosphorus application on quality parameters

Increasing the levels of phosphorus up to 60 $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ had significantly increased the protein content in grain and straw (Table 4.11). More protein content in grain and straw was observed might be because phosphorus is one of the key elements of Deoxyribose nucleic acid (DNA). Through the process of transcription and translation, DNA is ultimately converted to RNA to protein synthesis. The protein content is also influenced by availability of nitrogen content and nitrogen uptake which was found to be increased with higher level of phosphorus as there is a recognized correlation between the availability and uptake of nitrogen and phosphorus in plants with higher levels of phosphorus application. Similar results have also been reported by Togay *et. al* (2008) and Yumnan *et al.* (2018).

5.2.5 Economics of phosphorus levels

The detailed study on the economics of lentil was discussed in the earlier chapter where it was found that economics of lentil varies with various level of phosphorous. The highest cost of cultivation (29175.43 ₹ ha^{-1}), gross returns (63059.33 ₹ ha^{-1}), net returns (33833.90 ₹ ha^{-1}) and benefit-cost ratio (1.16) were recorded with the higher levels of phosphorus application i.e., 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$. This

might be due to higher grain and straw yield were recorded under higher fertility levels, this conform with the findings of Dwivedi *et al.* (2018).

5.3 Effect of PSB inoculation

5.3.1 Effect of PSB inoculation on growth parameters

Various growth parameters of lentil measured during the course of experimentation which were plant height, number of branches plant⁻¹, number of green leaves plant⁻¹, number of nodules plant⁻¹ and dry matter accumulation plant⁻¹ were found significantly affected by various levels of PSB seed inoculation. From table 4.1 to 4.5, it can be considered that growth parameters were highly influenced by seed inoculation with 10mL PSB kg⁻¹ seed over 0mL PSB kg⁻¹ seed inoculation. The highest value for plant height, number of branches plant⁻¹, number of green leaves plant⁻¹, number of nodules plant⁻¹ and dry matter accumulation plant⁻¹ were observed on seed treatment with 10mL PSB kg⁻¹ seed inoculation. This might be due to more availability of phosphorous to the soil as Phosphate Solubilizing Bacteria solubilizes native soil phosphorous bringing more phosphorous to soil. Seed inoculation with PSB makes soil porous which enhances other microbial activity and thus more micro and macro nutrients are available to the plant. Later, more phosphorus available to the plant enhances photosynthesis as it is directly involved in increase energy transfer reaction and essential for nitrogen fixing bacteria. The outcomes were revealed by Sharar *et al.* (2003), Kumari *et al.* (2009) and Singh *et al.* (2014).

5.3.2 Effect of PSB inoculation on yield attributes and yield

As previously mentioned, yield and yield attributing parameters which are number of pods plant⁻¹, number of grains pod⁻¹, test weight, grain yield, straw yield, biological yield, and harvest index of lentil were observed significantly higher in 10mL PSB kg⁻¹ seed inoculation than in 5mL PSB kg⁻¹ seed inoculation and no inoculation. This improvement was mostly owing to the conversion of insoluble phosphorus to a usable form. Increased phosphorus availability favored an increase in

phosphorus and nitrogen uptakes, which improved photosynthesis and resulted in better growth of the plant. Also, PSB inoculation increases root nodules which helps in higher rate of nitrogen fixation and ultimately enhances flowering and pod formation. The inoculation of seed with PSB resulted in the greater yield attributes, which resulted in increased yield later on. The results were in close conformity with Bera *et al.* (2013) and Singh *et al.* (2015).

5.3.3 Effect of PSB inoculation on nutrients content and uptake

On application of higher level PSB inoculation at 10mL PSB kg⁻¹ seed, the nitrogen, phosphorus, and potassium contents in grain and straw were increased (Table 4.8 to 4.10). The uptake of nitrogen, phosphorus, and potassium by grain and straw of lentil were considerably altered by PSB inoculation, and it was noted that a greater absorption of nutrient was recorded with 10mL PSB kg⁻¹ seed inoculation. PSB inoculation has a positive effect on the synthesis of additional photosynthates and chlorophyll content that may have aided in the improvement of nitrogen, phosphorus, and potassium levels. The PSB inoculation enhances the plant's hydration status, increasing its water uptake capacity and, as a result, improving dissolved nutrient uptake. PSB inoculation converts insoluble phosphate in the soil to a soluble form by secreting various organic acids such as formic, acetic, protonic, litotic, lactic, and others, which improves the nitrogen, phosphorus, and potassium content and uptake. This acid lowers the pH, causing the bound form of phosphate to dilute. As a result, vitamin supplementation combined with PSB inoculation in lentil may boost biological nitrogen fixation and phosphorus availability, results in increased nutrient uptake. Similar outcomes were revealed by Biswas *et al.* (2015) and Singh *et al.* (2015).

5.3.4 Effect of PSB inoculation on quality parameters

The data relevant to protein content and uptake as influenced by PSB levels indicated in table 4.11 revealed that seed inoculation with 10mL PSB kg⁻¹ seed found maximum protein content followed by 5mL PSB kg⁻¹ seed inoculation. This might be

due to more availability of nitrogen and phosphorus in the plant which stimulates protein synthesis in plants. The same findings were reported by Singh *et al.* (2014)

5.3.5 Effect of PSB inoculation on economics

Table 4.12 represents the data on the economics of treatment where the maximum total cost of cultivation (28282.56 ₹ ha⁻¹), gross return (60906.83 ₹ ha⁻¹), net return (32624.27 ₹ ha⁻¹) and B:C ratio (1.15) were obtained on seed inoculation with 10mL PSB kg⁻¹ seed followed by 5mL PSB inoculation kg⁻¹ seeds. The higher gross and net returns were obtained because more yield unit⁻¹ area was obtained on seed treatment with 10mL PSB kg⁻¹ seed inoculation. The results were in close conformity with the observation of Dwivedi *et. al* (2018).



SUMMARY AND CONCLUSION

This chapter attempts to summarize the results presented in the experimental findings chapter as well as to draw valid conclusions based on the significant findings of the current investigation entitled **“Effect of different levels of Phosphorus and Phosphate Solubilizing Bacteria (PSB) inoculation on growth and yield of Lentil (*Lens culinaris* Medik.) under Bael (*Aegle marmelos* L.) based Agri-horti system”**. The investigation took place in the Agricultural Research Farm of Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, during the winter (Rabi) season of 2019-20.

The soil in the experimental field was fairly fertile, with a low organic carbon content (0.38%) and accessible nitrogen ($162.35 \text{ kg ha}^{-1}$), as well as medium levels of available phosphorus (17.12 kg ha^{-1}) and potassium ($157.60 \text{ kg ha}^{-1}$). The experiment was carried out in bael orchard with 7*7 m spacing (fruit-based Agroforestry system). The experiment was carried out in factorial randomized block design. Phosphorus application was divided into three levels ($60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$, $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and $20 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) as well as PSB inoculation was divided into three levels (10mL PSB kg^{-1} seed inoculation, 5mL PSB kg^{-1} seed inoculation, and 0mL PSB kg^{-1} seed inoculation). Four times, the treatments were replicated. For “HUL-57” variety of lentil, the optimum quantity of required seeds were utilized (40 kg ha^{-1}) and sown with the use of kudal directly at a row to row and plant to plant distance of 30*5 cm respectively.

Plant height, number of branches plant^{-1} , number of green leaves plant^{-1} , number of root nodules plant^{-1} , dry matter accumulation plant^{-1} , number of pods plant^{-1} , number of grains pod^{-1} , test weight, grain yield, straw yield, biological yield, and nutrient (N, P, and K) content and uptake were all used to evaluate crop response to the treatments.

Get to a valid conclusion, the data obtained throughout the experimentation was statistically analyzed. Finally, the gross return, net return, and benefit-cost ratios of the various treatments were calculated. The study's key findings and broad conclusions are described below.

6.1 Effect of phosphorus levels

1. The plant height of lentil under bael based agri-horti system was significantly increased at various stages of crop but recorded maximum at harvest on the application of 60 kg P₂O₅ ha⁻¹.
2. The highest number of branches plant⁻¹ were found at harvest on the application of 60 kg P₂O₅ ha⁻¹ which was significantly higher than 20 kg P₂O₅ ha⁻¹ and remains statically at par with 40 kg P₂O₅ ha⁻¹.
3. The maximum number for green leaves plant⁻¹ were observed at 60 DAS rather than 30 and 90 DAS. On application of 60 kg P₂O₅ ha⁻¹ recorded the maximum number of green leaves plant⁻¹.
4. The maximum number of root nodules plant⁻¹ in lentil under bael based agri-horti system were recorded on the application of 60 kg P₂O₅ ha⁻¹ at 60 DAS.
5. With the advancement of crop stage, dry matter accumulation plant⁻¹ was increased at every stage and observed maximum at harvest. Application of 60 kg P₂O₅ ha⁻¹ found the highest dry matter accumulation plant⁻¹.
6. The number of pods plant⁻¹ were recorded maximum on the application of 60 kg P₂O₅ ha⁻¹ followed by 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹.
7. The maximum number of grains pod⁻¹ were recorded in treatment 60 kg P₂O₅ ha⁻¹.
8. The maximum test weight was obtained under the effect of 60 kg P₂O₅ ha⁻¹ which was significantly superior over 20 kg P₂O₅ ha⁻¹ but remains statically at par with 40 kg P₂O₅ ha⁻¹.
9. Grain, straw and biological yield were recorded maximum on the application of 60 kg P₂O₅ ha⁻¹ followed by 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹.

10. Harvest index was found non-significant with each levels of phosphorus.
11. The maximum nutrient content (N, P and K) were obtained in treatment 60 kg P_2O_5 ha⁻¹ followed by 40 kg P_2O_5 ha⁻¹ and 20 kg P_2O_5 ha⁻¹.
12. Nitrogen, phosphorus and potassium uptake varies significantly with different levels of phosphorus where the maximum uptake was observed in 60 kg P_2O_5 ha⁻¹ and the minimum in 20 kg P_2O_5 ha⁻¹.
13. Protein content and protein yield were increased with increasing levels of phosphorus. The highest protein content and yield was associated with 60 kg P_2O_5 ha⁻¹.
14. The maximum gross return (63059.33 ₹ ha⁻¹), net return (33883.90 ₹ ha⁻¹) and benefit-cost ratio (1.16) were obtained with 60 kg P_2O_5 ha⁻¹ followed by 40 and 20 kg P_2O_5 ha⁻¹ respectively.

6.2 Effect of PSB level

1. The maximum plant height was recorded with 10mL PSB kg⁻¹ seed inoculation which was significantly superior over 0mL PSB kg⁻¹ seed inoculation but remain statically at par with 5mL PSB kg⁻¹ seed inoculation.
2. The maximum number of branches plant⁻¹ were found at harvest on seed inoculation with 10mL PSB kg⁻¹ seed inoculation which were significantly higher than 0mL PSB kg⁻¹ seed inoculation and remains statically at par with 5mL PSB kg⁻¹ seed inoculation.
3. The number for green leaves plant⁻¹ were observed maximum at 60 DAS rather than 30 and 90 DAS on the application of 10mL PSB kg⁻¹ seed inoculation.
4. Application of 10mL PSB kg⁻¹ seed inoculation surpassed 0mL PSB kg⁻¹ seed inoculation but remains statically at par with 5mL PSB kg⁻¹ seed inoculation with respect to the number of root nodules plant⁻¹.
5. Dry matter accumulation plant⁻¹ of lentil under bael based agri-horti system were recorded highest in treatment 10mL PSB kg⁻¹ seed inoculation.

6. The highest number of pods plant⁻¹ were recorded on seed inoculation with 10mL PSB kg⁻¹ seed.
7. The maximum number of grains pod⁻¹ were recorded in treatment 10mL PSB kg⁻¹ seed inoculation.
8. The maximum test weight was obtained under the effect of 10mL PSB kg⁻¹ seed inoculation which was significantly superior over 0mL PSB kg⁻¹ seed inoculation but found statically at par with 5mL PSB kg⁻¹ seed inoculation.
9. On seeds inoculation with 10mL PSB kg⁻¹ seed, grain yield and straw yield were found significantly superior to 0mL PSB kg⁻¹ seed inoculation but remain statically at par with 5mL PSB kg⁻¹ seed inoculation.
10. The highest biological yield was obtained in treatment 10mL PSB kg⁻¹ seed inoculation and the lowest under 0mL PSB kg⁻¹ seed inoculation.
11. Harvest index was found non-significant with each level of phosphorus. The highest value of harvest index was found with the application of 10mL PSB kg⁻¹ seed inoculation followed by 5mL PSB kg⁻¹ seed inoculation and 0mL PSB kg⁻¹ seed inoculation.
12. The maximum nutrient content (N, P and K) were obtained in treatment 10mL PSB kg⁻¹ seed inoculation followed by 5mL PSB kg⁻¹ seed inoculation and 0 mL PSB kg⁻¹ inoculation.
13. Nitrogen, phosphorus and potassium uptake varies significantly with different levels of PSB where the maximum uptake was observed with 10mL PSB kg⁻¹ seed inoculation and minimum with 0mL PSB kg⁻¹ seed inoculation.
14. With increasing the levels of PSB, protein content and protein yield were increased. The highest protein content and yield were associated with 10mL PSB kg⁻¹ seed inoculation followed by 5mL PSB kg⁻¹ seed inoculation and 0mL PSB kg⁻¹ seed inoculation.
15. The maximum gross return (60906.83 ₹ ha⁻¹), net return (32624.27 ₹ ha⁻¹) and benefit-cost ratio (1.15) were obtained with 10mL PSB kg⁻¹ seed inoculation followed by 5mL and 0mL PSB kg⁻¹ seed inoculation.

16. The maximum gross return (147582.5 ₹ ha⁻¹), net return (98679.52 ₹ ha⁻¹) and B:C (2.02) ratio of lentil under bael based agri-horti system were observed in treatment 60 kg P₂O₅ ha⁻¹ along with 10mL PSB kg⁻¹ seed inoculation

Conclusion

- The maximum value of growth, yield and quality parameters of lentil crop were obtained in treatment 60 kg P₂O₅ ha⁻¹ along with 10mL PSB kg⁻¹ seed inoculation as compared to other levels of phosphorus application and seed inoculation with PSB.
- The highest net profit (lentil crop + bael tree) were obtained with the application of phosphorus at 60 kg P₂O₅ ha⁻¹ in combination with 10mL PSB kg⁻¹ seed inoculation under bael based agri-horti system.

Since these outcomes are based on single crop season data only, the experiment needs to be repeated for one to two seasons more to reach the final validation and recommendation to the farming community.



BIBLIOGRAPHY

- Ahmed, F. R. S., Alexander, I. J., Mwinyihija, M., & Killham, K. (2011). Effect of superphosphate and arbuscular mycorrhizal fungus *Glomus mosseae* on phosphorus and arsenic uptake in lentil (*Lens culinaris* L.). *Water, Air, and Soil Pollution*, 221(1), 169-182.
- Ali, A., Ahmad, B., Hussain, I., Ali, A., & Shah, F. A. (2017). Effect of phosphorus and zinc on yield of lentil. *Pure and Applied Biology (PAB)*, 6(4), 1397-1402.
- Ali, M. A., Abbas, G., Mohy-ud-Din, Q., Ullah, K., Abbas, G., & Aslam, M. (2010). Response of mungbean (*Vigna radiata*) to phosphatic fertilizer under arid climate. *Journal of Animal and Plant Sciences*, 20(2), 83-86.
- Ansari, J., Sharma, C. P., Sagar, A., & Fatma, A. (2015). Interactive effect of bio-fertilizers (Rhizobium, PSB and VAM) in lentil (*Lens culinaris* L.). *Research in Environment and Life Sciences*, 8, 613-614.
- Ayub, M., Nadeem, M. A., Naeem, M., Tahir, M., Tariq, M., & Ahmad, W. (2012). Effect of different levels of P and K on growth, forage yield and quality of cluster bean (*Cyamopsis tetragonolobus* L.). *Journal of Animal and Plant Sciences*, 22(2).
- Balai, K., Jajoria, M., Verma, R., Deewan, P., & Bairwa, S. K. (2017). Nutrient content, uptake, quality of chickpea and fertility status of soil as influenced by fertilization of phosphorus and zinc. *Journal of Pharmacognosy and Phytochemistry*, 6(1), 392-398.
- Barua, R., Bhuiya, M. S. U., Kabir, M. M., Maniruzzaman, S., & Ahmed, Z. (2011). Effects of mimosa (*Mimosa invisa*) compost and phosphorus on the yield and yield components of lentil (*Lens culinaris* L.). *The Agriculturists*, 9(1-2), 63-72.
- Bera, A. K., Pramanik, K., & Panda, D. (2013). Response of biofertilizers and homobrassinolide on growth, relative water content and yield of lentil (*Lens culinaris* Medik). *Journal of Crop and Weed*, 9(2), 84-90.
- Bhavaya, G., Chandra Shaker, K., Jayasree, G., & Reddy, M. M. (2018). Nutrient uptake and yield of green gram (*Vigna radiata* L.) as influenced by phosphorus fertilization, organic manures and biofertilizers. *International Journal of Chemical Studies*, 6(3), 32-35.
- Biswas, P. K., Bhowmick, M. K., Kundu, M. C., Mondal, S., & Ghosh, G. K. (2015). Conjoint application of biofertilizer and phosphorous levels on growth, nodulation, nutrient uptake and productivity of lentil (*Lens culinaris* Medikus)

- in red and lateritic soils of West Bengal. *Journal Crop and Weed*, 11(1), 29-32.
- Black, C. A., D. D., Evans, J. L., White, L. E., Ensminger, F. E., Clark and Dinauer, R. C. (1965). Methods of soil analysis, *American Society of Agronomy*, Monogr, No. 9, Madison, Wis. 1572 p, (2).
- Chandrakar H. L., Chandrakar K., Manas Ujjaini and Yadav K. C. (2014). The effect of fertilization on growth & yield of rain fed Blackgram in Bael based Agri-horti-system with Alley Cropping Pattern on Vindhyan soil. *International Journal of Scientific and Research Publications*, 4: 2250-3153.
- Chauhan, S. V. S., & Raghav, B. S. (2017). Effect of phosphorus and phosphate solubilizing bacteria on growth, yield and quality of chickpea (*Cicer arietinum*). *Annals of Plant and Soil Research*, 19(3), 303-306.
- Chaurasiya, P., Kumar, S., Verma, A., & Kumawat, L. (2020). Effect of PSB Inoculation with and Without P and S Application on Productivity of Mungbean (*Vigna radiata* L.) in Western UP India. *International Journal of Current Microbiology and Applied Sciences*, 9(3), 2418-2426.
- Choubey, S. K., Dwivedi, V. P., & Srivastava, N. K. (2013). Effect of different levels of phosphorus and sulphur on growth, yield and quality of lentil (*Lens culinaris* M). *Indian Journal of Scientific Research*, 4(2), 149-150.
- Cordell, D., Drangert, J. O., & White, S. (2009). The story of phosphorus: global food security and food for thought. *Global Environmental Change*, 19(2), 292-305.
- Dashadi, M., Hossein, A., Radjabi, R., & Babainejad, T. (2013). Investigation of effect different rates phosphorus and zinc fertilizers on two cultivars lentil gachsaran and (flip92-121) in irrigation complement condition. *International Journal of Agriculture and Crop Sciences (IJACS)*, 5(1), 1-5.
- Datta, S. K., Sarker, M. A. R., & Uddin, F. M. J. (2013). Effect of variety and level of phosphorus on the yield and yield components of lentil. *International Journal of Agricultural Research, Innovation and Technology*, 3(1), 78-82.
- Dhewaj, S., Singh, Y., Sulochana and Bajia, R. (2015). Effect of Phosphorus levels and PSB on growth indices and yield of green gram (*Vigna radiata* L.) under custard apple (*Annona squamosa* L.) based agri- horti system. *The Bioscan*, 10(3): 1317-1320.
- Dwivedi, R. K., & Dwivedi, K. P. (2018). Effect of phosphorus, sulphur and biofertilizers on growth, yield and quality of lentil (*Lens culinaris* L.). *Crop Research*, (0970-4884), 53.

- Fatima, K., Hussain, N., Pir, F. A., & Mehdi, M. (2013). Effect of nitrogen and phosphorus on growth and yield of Lentil (*Lens culnaris*). *Elixir International Journal*, 57, 14323-14325.
- Gupta, A., Sharma, V. K., Sharma, G. D., & Chopra, P. (2006). Effect of biofertilizer and phosphorus levels on yield attributes, yield and quality of urdbean (*Vigna mungo*). *Indian Journal of Agronomy*, 51(2), 142-144.
- Hojjat, S., & Taherzadeh, A. (2013). Effect of integrated application of a complex fertilizer (N30P50) on nitrogen fixation by Lentil (*Lens culinaris* Medik.). *International Journal of Agriculture and Crop Sciences (IJACS)*, 5(8), 896-899.
- Jackson, M. L. (1973) Soil chemical analysis, Prentice Hall Private Limited, New Delhi, pp, 183-204.
- Katiyar, D., Kumar, S., & Singh, N. (2020). Effect of Rhizobium and PSB inoculation on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.). *International Journal of Chemical Sciences International*, 8(4), 3729-3734.
- Khanna, V., & Sharma, P. (2011). Potential for enhancing lentil (*Lens culinaris*) productivity by co-inoculation with PSB, plant growth-promoting rhizobacteria and Rhizobium. *Indian Journal of Agricultural Sciences*, 81(10), 932.
- Kumar, D., Arvadiya, L. K., Kumawat, A. K., Desai, K. L. And Patel, T. U. (2014). Yield, protein content, nutrient content and uptake of chickpea (*Cicer arietinum* L.) as influenced by graded levels of fertilizers and bio-fertilizers. *Research Journal of Chemical and Environmental Sciences*, 2(6): 60-64.
- Kumar P., Pandey, S. K. and Kumar, P. (2015). Effect of Different Phosphorus Levels on Nutrient Content, Uptake and Economics of Urd bean under bael based Agri-Horti System. *Journal of Agriculture research*, 2(2): 88-93.
- Kumari, M., Vasu, D., Ul-Hasan, Z., & Dhurwe, U. K. (2009). Effects of PSB (Phosphate Solubilizing Bacteria) on morphological characters of *Lens culinaris* Medic. In *Biological Forum*, 1: 5-7.
- Kumawat, N., Kumar, R., & Sharma, O. P. (2009). Nutrient uptake and yield of mungbean [*Vigna radiata* (L.) Wilczek] as influenced by organic manures, PSB and phosphorus fertilization. *Ecology, Environment and Conservation*, 27(4B), 2002-2005.
- Laharia, G. S., Apotikar, V., Age A. B., Gite, P. A. and Deshmukh, D. P. (2019). Effect of Phosphorus levels with PSB on yield, nutrient use efficiency and

- uptake of nutrients by chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry*, 8(3): 3182-3185
- López-Arredondo, D. L., Leyva-González, M. A., González-Morales, S. I., López-Bucio, J., & Herrera-Estrella, L. (2014). Phosphate nutrition: improving low-phosphate tolerance in crops. *Annual Review of Plant Biology*, 65: 95-123.
- Mansur, C. P., Palled, Y. B., Halikati, S. I., Salimath, P. M. and Chetti, M. B. (2009) Effect of plant densities and Phosphorus levels on seed yield and protein content of *Kabuli* chickpea (*Cicer kabulum* L.) genotypes. *Karnataka Journal of Agriculture Science*, 22(2): 267-270.
- Mitran, T., Meena, R. S., Lal, R., Layek, J., Kumar, S., & Datta, R. (2018). Role of soil phosphorus on legume production. In *Legumes for Soil Health and Sustainable Management*, (pp. 487-510). Springer, Singapore.
- Nair, P. K. R. (1984). Tropical agroforestry systems and practices. *Tropical Resource Ecology and Development*, John Wiley, Chichester. England, 1-23.
- Niri, H. H., Tobeh, A., Gholipouri, A., Zakaria, R. A., Mostafaei, H., & Jamaati-e-Somarin, S. (2010). Effect of nitrogen and phosphorous on yield and protein content of lentil in dryland condition. *American-Eurasian Journal of Agricultural and Environmental Sciences*, 8(2), 185-188.
- Olsen, S. R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). *US Department of Agriculture*.
- Palsaniya D. R., Khan M. A., Tewari R. K. and Bajpai C. K. (2012). Tree crop interaction in *Psidium guajava* based agri-horti system. *Range Management and Agroforestry*, 33(1), 32 -36.
- Pandey, M. K., Verma, A., & Kumar, P. (2016). Effect of integrated phosphorus management on growth, yield and quality of lentil (*Lens culinaris*). *Indian Journal of Agricultural Research*, 50(3).
- Pandey, S. B., Nigam, R. C., & Singh, L. (2019). Yield, yield attributing characters and nitrogen uptake of lentil as influenced by phosphorus and sulphur levels in Gangetic alluvial soil of Uttar Pradesh. *Crop Research*, (0970-4884), 54.
- Patel, S., Singh, S. K., Singh, T., & Bhagat, S. (2018). Effect of fertility levels and varieties of lentil (*Lens culinaris* Medikus). *Journal of Pharmacognosy and Phytochemistry*, 7(3), 2725-2727.
- Piper, C. S. (1966). Soil and plant analysis, Hans. *Publication Bombay. Asian Journal of Education and Social Studies*, 368-374.

- Prajapati, B. J., Gudadhe, N., Gamit, V. R. and Chhaganiya, H. J. (2017). Effect of integrated Phosphorus management on growth, yield attributes and yields of chickpea (*Cicer arietinum* L.). *Farming and Management*, 2(1): 36-40.
- Rasheed, M., Jilani, G., Shah, I. A., Najeeb, U., & Iqbal, T. (2010). Improved lentil production by utilizing genetic variability in response to phosphorus fertilization. *Acta Agriculturae Scandinavica - Section B Soil and Plant Science*, 60(6), 485-493
- Rasool, S., & Singh, J. (2016). Effect of Bio-fertilizers and Phosphorus on Growth and Yield of Lentil (*Lens culinaris* L.). *International Journal of Advances in Agricultural Science and Technology*, 3(7), 35-42.
- Rotaru, V., & Sinclair, T. R. (2009). Interactive influence of phosphorus and iron on nitrogen fixation by soybean. *Environmental and Experimental Botany*, 66(1), 94-99.
- Sadeghipour, O., Monem, R., & Tajali, A. A. (2010). Production of mungbean (*Vigna radiata* L.) as affected by nitrogen and phosphorus fertilizer application. *Journal of Applied Sciences*, 10(10), 843-847.
- Schwember, A. R., Schulze, J., Del Pozo, A., & Cabeza, R. A. (2019). Regulation of symbiotic nitrogen fixation in legume root nodules. *Plants*, 8(9), 333.
- Sharar, M. S., Ayub, M., Nadeem, M. A., & Naeem, M. (2003). Effect of different combinations of nitrogen and phosphorus on the growth and yield of three varieties of lentil (*Lens culinaris* Medik). *Pakistan Journal of Life and Social Sciences*, 1(1), 54-56.
- Shukla, R. D., Singh, A., Verma, S., Singh, A. K., Dubey, D., & Kumar, S. (2017). Effect of crop geometry and phosphorus levels on growth and productivity of chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry*, 6(5), 659-661.
- Singh, A. V., & Prasad, B. (2014). Enhancement of plant growth, nodulation and seed yield through Plant Growth Promoting Rhizobacteria in Lentil (*Lens culinaris* Medik cv. VL125). *International journal of current Microbiology and Applied Sciences*, 3(6), 614-622.
- Singh, A. V., Prasad, B., & Goel, R. (2018). Plant growth promoting efficiency of phosphate solubilizing *Chryseobacterium* sp. PSR 10 with different doses of N and P fertilizers on lentil (*Lens culinaris* var. PL-5) growth and yield. *International Journal of Current Microbiology and Applied Sciences*, 7(05), 2280-2289.

- Singh, A. V., Prasad, B., & Shah, S. (2011). Influence of phosphate solubilizing bacteria for enhancement of plant growth and seed yield in lentil. *Journal of Crop and Weed*, 7(1), 1-4
- Singh, D Harvendra., Khare, Archana., & Singh, Sukhvir. (2017). Effect of phosphorus and molybdenum nutrition on yield and nutrient uptake in lentil (*Lens culinaris* L). *Annals of Plant and Soil Research*, 19(1), 37-41.
- Singh, G., Ram, H., Sekhon, H. S., Aggarwal, N., & Khanna, V. (2011). Effect of nutrient management on nodulation, growth and yield of lentil (*Lens culinaris* Medik.) genotypes. *American-Eurasian Journal of Agronomy*, 4(3), 46-49.
- Singh, G., Sekhon, H. S., Ram, H., & Sharma, P. (2010). Effect of farmyard manure, phosphorus and phosphate solubilizing bacteria on nodulation, growth and yield of kabuli chickpea. *Journal of Food Legumes*, 23(3and4): 226-229.
- Singh, G., Virk, H. K., Aggarwal, N., Gupta, R. K., & Khanna, V. (2019). Symbiotic parameters, growth, nutrient accumulation, productivity and profitability as influenced by integrated nutrient management in lentil (*Lens culinaris*). *Archives of Agronomy and Soil Science*, 65(3): 411-420.
- Singh, K. K., Srinivasarao, C., & Ali, M. 2005. Root growth, nodulation, grain yield, and phosphorus use efficiency of lentil as influenced by phosphorus, irrigation, and inoculation. *Communications in Soil Science and Plant Analysis*, 36(13-14), 1919-1929.
- Singh, N., & Singh, G. (2016). Response of lentil (*Lens culinaris* Medikus) to phosphorus-A review. *Agricultural Reviews*, 37(1), 27-34.
- Singh, N., Singh, G., Aggarwal, N., & Khanna, V. (2018). Yield enhancement and phosphorus economy in lentil (*Lens culinaris* Medikus) with integrated use of phosphorus, Rhizobium and plant growth promoting rhizobacteria. *Journal of Plant Nutrition*, 41(6), 737-748.
- Singh, Ranjit., & Pandey, Manoj. (2017). Effect of phosphorus on yield, quality and uptake of nutrients in lentil (*Lens culinaris*) cultivars. *Annals of Plant and Soil Research*, 19(4), 418-421.
- Singh, R., Pratap, T., Singh, D., Singh, G., & Singh, A. K. (2018). Effect of phosphorus, Sulphur and biofertilizers on growth attributes and yield of chickpea (*Cicer arietinum* L.). *Journal Pharmacognosy Phytochemistry*, 7, 3871-3875.
- Singh, R., Singh, V., Singh, P., & Yadav, R. A. (2018). Effect of phosphorus and PSB on yield attributes, quality and economics of summer greengram (*Vigna radiata* L.). *Journal of Pharmacognosy and Phytochemistry*, 7(2), 404-408.

- Singh, V., Ali, J., Singh, H., & Singh, J. P. (2016). Effect of sources of phosphorus and biofertilizers on yield, nutrient uptake and quality of lentil. *Annals of Plant and Soil Research*, 18(1), 14-17.
- Singh, V., Thenua, O. V. S., & Shivay, Y. S. (2017). Effect of phosphorus nutrition on chickpea (*Cicer arietinum* L.) in sunflower-chickpea cropping system. *International Journal of Scientific Progress and Research*, 12, 2371-2378.
- Srinivasan K., Ashokan P. K., Kunhamu T. K., Navas I. E. and Eldho V. (2010). Influence of multipurpose trees on physic-chemical properties of soil in coconut based agroforestry systems. *Indian Journal of Agroforestry*, 12 (2): 6-
- Subbiah, B. V. and Asija, G. L. (1956). A rapid procedure for the determination of available nitrogen in soil. *Current Science*, 25, 259-260.
- Tagore, G. S., Namdeo, S. L., Sharma, S. K., & Kumar, N. (2014). Effect of Rhizobium and phosphate solubilizing bacterial inoculants on symbiotic traits, nodule leghemoglobin, and yield of chickpea genotypes. *International Journal of Agronomy*, 581627, 1-8.
- Thorlakson, T., & Neufeldt, H. (2012). Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture and Food Security*, 1(1), 1-13.
- Togay, Y., Togay, N., and Dogan, Y. 2008. Research on the effect of phosphorus and molybdenum applications on the yield and yield parameters in lentil (*Lens culinaris* Medic.). *African Journal of Biotechnology*, 7(9).
- Vance, C. P., Uhde-Stone, C., & Allan, D. L. (2003). Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. *New Phytologist*, 157(3), 423-447.
- Walkley, A. J. and Black, C. A. (1934) Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*, 37, 29-38.
- Yadav, B. K., & Kumar, S. (2014). Performance of chickpea (*Cicer arietinum*) under different levels of phosphorous and sulphur application. *Plant Archives*, 14(2), 1115-1117.
- Yadav, S. P., & Bhasker, P. (2017). Response of phosphorus, Rhizobium and phosphate solubilizing bacteria interaction studies on growth, nodulation and yield of lentil [*Lens culinaris* Medikus]. *Annals of Agri Bio Research*, 22(1), 9-12.
- Yuman, T., Luikham, E., and Singh, H. (2018). Influence of phosphorus on Growth and Yield of Promising Varieties of Lentil (*Lens culinaris* L.). *International Journal of Current Microbiology and Applied Sciences*, 7(8): 162-170.

- Zafar, N., Munir, M. K., Ahmed, S., & Zafar, M. (2020). Phosphorus Solubilizing Bacteria (PSB) in combination with different Fertilizer sources to enhance yield performance of chickpea. *Life Science Journal*, 17(8).
- Zaidi, A., Khan, M. S., Rizvi, A., Saif, S., Ahmad, B., & Shahid, M. (2017). Role of phosphate-solubilizing bacteria in legume improvement. In *Microbes for legume improvement*, (pp. 175-197). Springer, Cham.
- Zeidan, M. S. (2007). Effect of organic manure and phosphorus fertilizers on growth, yield and quality of lentil plants in sandy soil. *Research journal of agriculture and biological sciences*, 3(6), 748-752
- Zhang, Z., Liao, H., & Lucas, W. J. (2014). Molecular mechanisms underlying phosphate sensing, signaling, and adaptation in plants. *Journal of Integrative Plant Biology*, 56(3), 192-220.



Appendices

Appendix I: Common cost of cultivation of lentil

S. No.	Operations	Input	Rate (₹ unit ⁻¹)	Cost (₹ ha ⁻¹)
1	Conventional tillage			
	(i) One deep ploughing by tractor for 2 hours	One Tractor (35 HP) for 2 hrs.	600 ₹ hrs ⁻¹	1200
	(ii) One harrowing and planking	One Tractor (35 HP) for 4 hrs	600 ₹ hrs ⁻¹	2400
2	Layout	4 labour	290 ₹ labour ⁻¹ day ⁻¹	1160
3	Biofertilizer inoculation preparation	2 labour	290 ₹ labour ⁻¹ day ⁻¹	580
4	Seed sowing	10 labour	290 ₹ labour ⁻¹ day ⁻¹	2900
5	Irrigation (2)	Water for two irrigations	500 ₹ irrigation ⁻¹ ha ⁻¹	1000
6	Thinning and weed management	15 labour	290 ₹ labour ⁻¹ day ⁻¹	4350
9	Harvesting and Threshing	20 labour	290 ₹ labour ⁻¹ day ⁻¹	5800
10	Seed cost	40 kg ha ⁻¹	80 ₹ kg ⁻¹	3200
Total				22590

Appendix II: Treatment wise cost of cultivation of lentil

Treatments	Quantity of required nutrient	Input	Rate (₹ unit ⁻¹)	Cost (₹ ha ⁻¹)
P1	20 kg P ₂ O ₅ ha ⁻¹	43.47 kg DAP ha ⁻¹	22.5 ₹ kg	978.08
P2	40 kg P ₂ O ₅ ha ⁻¹	86.95 kg DAP ha ⁻¹	22.5 ₹ kg	1956.38
P3	60 kg P ₂ O ₅ ha ⁻¹	130.43 kg DAP ha ⁻¹	22.5 ₹ kg	2934.68
B1	0mL PSB ha ⁻¹	-	-	
B2	5mL PSB ha ⁻¹	200mL PSB ha ⁻¹	360 ₹ l ⁻¹	72.00
B3	10mL PSB ha ⁻¹	400mL PSB ha ⁻¹	360 ₹ l ⁻¹	144.00
N1	20 kg N ha ⁻¹	26.47 kg urea ha ⁻¹	6.0 ₹ kg ⁻¹	158.82
N2	20 kg N ha ⁻¹	9.45 kg urea ha ⁻¹	6.0 ₹ kg ⁻¹	56.70
N3	20 kg N ha ⁻¹	0	6.0 ₹ kg ⁻¹	0.00
RDF				
Common fertilizer	a.) 20 kg K ₂ O ha ⁻¹	33.33 kg MOP ha ⁻¹	18 ₹ kg ⁻¹	600
	b.) 20 kg S ha ⁻¹	22.2 kg S ha ⁻¹	45 ₹ kg ⁻¹	1000

Appendix III: Total cost of cultivation of lentil

Treatment	General cost of cultivation (₹ ha ⁻¹)	Common fertilizer cost (₹ ha ⁻¹)	Treatment wise fertilizer cost (₹ ha ⁻¹)	Working capital (₹ ha ⁻¹)	Interest on working capital @ 14% annum ⁻¹ (₹ ha ⁻¹)	Land revenue (₹ ha ⁻¹)	Total cost (₹ ha ⁻¹)
P ₁ B ₁	22590	1600	1136.89	25326.89	1772.88	75	27174.77
P ₂ B ₁	22590	1600	2013.07	26203.07	1834.21	75	28112.28
P ₃ B ₁	22590	1600	2934.64	27124.64	1898.72	75	29098.36
P ₁ B ₂	22590	1600	1208.89	25398.89	1777.92	75	27251.81
P ₂ B ₂	22590	1600	2085.07	26275.07	1839.25	75	28189.32
P ₃ B ₂	22590	1600	3006.67	27196.67	1903.76	75	29175.44
P ₁ B ₃	22590	1600	1280.89	25470.89	1782.96	75	27328.85
P ₂ B ₃	22590	1600	2157.07	26347.07	1844.29	75	28266.36
P ₃ B ₃	22590	1600	3078.67	27268.67	1908.80	75	29252.48

Appendix IV: Economics of Lentil

Treatment	Total Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)			Net return (₹ ha ⁻¹)	B:C Ratio
		Grain return	Straw return	Total		
P ₁ B ₁	27174.77	44328.00	2612.00	46940.00	19765.23	0.72
P ₂ B ₁	28112.28	46644.00	2761.50	49405.50	21293.22	0.75
P ₃ B ₁	29098.36	49992.00	3024.00	53016.00	23917.64	0.82
P ₁ B ₂	27251.81	47952.00	2853.50	50805.50	23533.69	0.86
P ₂ B ₂	28189.32	56256.00	3124.00	59380.00	31190.68	1.10
P ₃ B ₂	29175.44	62736.00	3363.50	66099.50	36924.06	1.26
P ₁ B ₃	27328.85	48624.00	2954.00	51578.00	24249.15	0.88
P ₂ B ₃	28266.36	57912.00	3168.00	61080.00	32813.64	1.16
P ₃ B ₃	29252.18	66600.00	3462.50	70062.50	40810.32	1.39

Appendix V: Cost of cultivation of bael

S.No.	Operation	Input	Rate (` unit <sup>-1</sup>)	Cost (` ha ⁻¹)
1	Nitrogen = 500 g plant ⁻¹	201.78 kg Urea ha ⁻¹	6.0 ` kg ⁻¹	1210.68
	Phosphorus = 250 g plant ⁻¹	110.86 kg DAP ha ⁻¹	22.5 ` kg ⁻¹	2494.35
	Potassium = 500 g plant ⁻¹	170 kg MOP ha ⁻¹	18 ` kg ⁻¹	3060
	Fertilizer application	5 labour	290 ` labour ⁻¹ day ⁻¹	1450
2	Weeding and pruning	15 labour	290 ` labour ⁻¹ day ⁻¹	4350
3	Harvesting	20 labour	290 ` labour ⁻¹ day ⁻¹	5800
4	Working capital (`)			18365.03
5	Interest on working capital @ 14 % annum ⁻¹ (`)			1285.55
Total cost of bael cultivation = 19650.5				

Appendix VI: Economics of lentil under bael based agri-horti system

Treatment	Total Cost of cultivation lentil + fruit tree ha ⁻¹ (` ha <sup>-1</sup>)	Gross return ha <sup>-1</sup> (` ha ⁻¹)			Net return (` ha ⁻¹)	B:C Ratio
		Lentil return	Fruit tree return	Total		
P ₁ B ₁	46825.27	46940.00	77520.00	124460.00	77634.73	1.66
P ₂ B ₁	47762.78	49405.50	77520.00	126925.50	79162.72	1.66
P ₃ B ₁	48748.86	53016.00	77520.00	130536.00	81787.14	1.68
P ₁ B ₂	46902.31	50805.50	77520.00	128325.50	81423.19	1.74
P ₂ B ₂	47839.82	59380.00	77520.00	136900.00	89060.18	1.86
P ₃ B ₂	48825.94	66099.50	77520.00	143619.50	94793.56	1.94
P ₁ B ₃	46979.35	51578.00	77520.00	129098.00	82118.6	1.75
P ₂ B ₃	47916.86	61080.00	77520.00	138600.00	90683.14	1.89
P ₃ B ₃	48902.98	70062.50	77520.00	147582.5	98679.52	2.02

