Effect of nitrogen, phosphorus and sulphur doses and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system

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BANARAS HINDU UNIVERSITY

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF

Master of Science (Agriculture)
in
Agroforestry

Supervisor
Prof. M. K. Singh

Submitted by
Vikash Kumar

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CERTIFICATE

To
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Through: The Head, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, 221005

Dear Sir,

I have great pleasure in forwarding the thesis entitled **"Effect of nitrogen, phosphorus and sulphur doses and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** submitted by **Mr. Vikash Kumar [ID. No. 20430AGF028, Enrolment No. 431550]** in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in **Agroforestry,** Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and placing on record that she has completed the requisite residential requirements as contained in the statute 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.

Forwarded by Yours faithfully,

(Prof. M. K. Singh)

Head **Supervisor**

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Date:

Place:** Varanasi* ***(Vikash Kumar)

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LIST OF SYMBOLS AND ABBREVIATIONS

@	at the rate of	m	Meter
%	Per cent	Max.	Maximum
°C	Degree Celsius	ppm	Part per million
ANOVA	Analysis of variance	Min.	Minimum
B:C	Benefit-cost ratio	Mg	Milligram
cm	Centimeter	N	Nitrogen
CV	Co-efficient of variance	No.	Number
d.f.	Degree of freedom	NS	Non-significant
FAO	Food and Agriculture Organization	P	Phosphorus
DAS	Days after sowing	pH	Puissance dehydrogen
PF	Pre-flowering	R.H.	Relative humidity
dSm^{-1}	Deci-siemens per metre	$^{-1}$	per
EC	Electrical conductivity	₹	Rupees
et al.	And co-workers	*fb*	followed by
PI	Pod initiation	GP	Guava plantation
DNPS	Doses of Nitrogen + Phosphorus + Sulphur	mm	Millimeter
CUFS	Concentrations of Urea as Foliar Spray	MOP	Muriate of potash
t	Ton	CD	Critical difference
Fig.	Figure	S. No.	Serial number
g	Gram	S.Em±	Standard error of mean
ha	Hectare	S	Sulphur
i.e.	that is	*viz.*	(videlicet) namely
K	Potassium	DAP	Di-ammonium sulphate
kg	Kilogram	KCl	Potassium chloride

Chapter I

INTRODUCTION

The development of human civilization with significant industrialization and urbanization ultimately led to global climate change and land degradation by endangering our food and energy security, which resulted in declining living standards and the extinction of species (Gomes *et al*., 2019; Shastri and Gosh, 2019). Land degradation" is the term used to describe a decline in the quality or ability of the land to support production, and it can be caused by a variety of physical, chemical, and biological processes that are either directly or indirectly affected by human activity such as salinity, alkalization, loss of soil nutrients, a decline in soil organic matter (SOM), and soil compaction (Acharya and Kafle, 2009). Soil erosion is one of the main challenges for land managers since almost 60% of the world's land surface is considered to be degraded due to soil erosion (Pimentel., 2006). According to data from the Forest Survey of India (FSI), 2015 report, the total area covered by trees and forests in UP is just 8.82% (tree cover 2.86% + forest cover 5.96%) (Verma *et al*., 2017).

Agroforestry is a method of land management that incorporates trees into agricultural systems, allowing for the maintenance of trees, crops, and animals on the same piece of land for financial, ecological, and social benefits. Agroforestry is a dynamic, ecologically oriented natural resource management method that integrates with trees on fields and in the agricultural landscape to vary and sustain production for enhanced social, economic, and environmental benefits for land users at all levels. The International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD) says that agroforestry is a "win-win" multifunctional land use system that balances the production of goods (food, feed, fuel, fibre, etc.) while also supplying recreational opportunities (IAASTD, 2008). Agroforestry is one of these alternative solutions to dealing with the problems created by resource depletion, climate change and land degradation. The agroforestry system is advantageous with respect to long-term soil stability and production (Kirby and Potvin, 2007; Nair *et al*., 2009).

The agri-horticulture system is a multi-land use system that provides farmers with a high economic return on their investment. The tree and crop aspects support each other in the initial stages of orchard establishment in such a way that agri-horticultural systems provide sustainable green land use and a higher financial benefit than the corresponding sole crop, and the interaction between the factors is complementary in nature and beautiful under rainfed conditions. It's an agricultural approach used in India to help farmers make the most of the growing season by increasing production per unit area.

Guava is one of India's most important fruit crops (*Psidium guajava* L.). It contributes about 3.3% of India's total fruit production and around 3.3% of the country's overall cropland. India's largest producer is Uttar Pradesh, which also produces the best-quality guava in the world in the Allahabad area. Guava is rich in ascorbic acid. It's rich in dietary fibre and pectin. It can be made into jam, jelly, nectar, juice, guava cake, puree, and more. The roots, bark, leaves, and fruits of this plant are all very beneficial. The common guava has quadrangular branchlets, oval to oblong leaves that are 7.6 cm (3 inches) in length, and white flowers that are 2.5 cm (1 inch) in diameter and have four petals. The fruits are round to pear-shaped, with a pulp containing several small hard seeds and a diameter of up to 7.6 cm. This tree makes excellent fuelwood because of its light-yellow sapwood and brownish heartwood, which are soft, light, and weak (Orwa *et al*., 2009).

Pulses have long been an important component of a sustainable crop-production system due to their ability to fix biological nitrogen, low water requirements, and ability to withstand harsh weather. Pulses are a major source of protein and a staple in the diets of India's poor and vegetarian populations. Pulses provide an excellent vegetarian protein that has a high biological value when combined with cereals. According to household consumption surveys, pulse consumption is declining, resulting in an increase in malnutrition and a decrease in protein intake. More than 25% of the world's malnutrition is found in India (Bhavani and Swaminathan, 2013). Malnutrition affects 15.2% of India's population. This emphasizes the importance of pulses in ensuring food security for the Indian population.

Lentil (*Lens culinaris* Medik.) is a major cool-season grain legume crop in India, and after chickpea, it is the second most cultivated legume during the winter. Lentil is a part of the Fabaceae family (Leguminosae). Lentil is a self-pollinating crop. Being a legume, it relies on *Rhizobium* bacteria to fix nitrogen through root nodules, which reduces the requirements for nitrogen fertilizers. Because of its high protein content, which ranges from 20.6-31.4%, it occupies a special place in the agricultural world (Urbano *et al*., 2007). It's a bushy annual legume plant with lens-shaped seeds. It grows upto a height of about 40 cm (16 inches) and produces seeds in pods with two seeds each. Lentil offers a variety of colours including yellow, red, orange, green, brown, and black. Lentil are available whole or split, with or without the skins, and in a range of sizes (Kumar *et al*., 2022). The appropriate management practices and the optimum amounts of required inputs can help a variety reach its maximum yield potential. The response of various doses of nitrogen + phosphorus + sulphur and concentrations of urea as foliar spray is important because varieties differ in their growth and developmental behaviours.

Nitrogen is an essential macronutrient for plant function and it is also a key component of amino acids, which form the building blocks of plant proteins and enzymes. It is one of the limiting factors in crop production. The application of nitrogen leads to higher biomass, protein yield and enzyme synthesis. All living things are made of proteins, and enzymes help with the vast variety of biochemical processes that take place within them. Nitrogen influences the amino acid content and improves nutritional value. Additionally, nitrogen is also a component of chlorophyll which helps plants to perform photosynthesis and promote plant growth and increase yield (Blumenthal *et al*., 2008).

Phosphorus is an essential macronutrient required for plant growth, development, and metabolism. It is necessary for the growth, development, and metabolism of immature tissue. It's also considered "the key to life" because it influences several metabolic processes in the plant. Plants take phosphorus more as the primary orthophosphate ion ($H_2PO_4^-$), but secondary orthophosphate ($H_2PO_4^{-2}$) is also absorbed. Phosphorus enhances the crop's durability, and a sufficient amount of phosphorus promotes rapid growth. Phosphorus is an essential component for successful pulse production because it promotes root growth, stalks or stem strength, flower or seed formation, crop maturity, nitrogen fixation, crop quality, and disease resistance *via.* boosting physiological processes. It increases yields of legume crops by promoting biological activity in the soil and rhizosphere, such as nodulation, nitrogen fixation, and nutrient absorption. Phosphorus therapy reduces the adverse effects of drought on physiological parameters and increases yield in drought-stricken areas.

Sulphur is the most important and essential nutrient for plants (Nazar *et al*., 2011). It is necessary for the production of proteins, chlorophyll, and the amino acids cysteine, cystine, and methionine. Sulphur affects the metabolic activity of plants as well. Sulphur also promotes nodulation in legumes, and helps to develop and activate certain enzymes and vitamins. High-yielding pulse crops cannot be grown in many parts of the nation due to inadequate soil sulphur concentrations. The country's sulphur deficits have been exacerbated in recent years as a result of the adoption of recurrent and intensive cropping and the widespread use of sulphur-free fertilizers.

Foliar application of nutrients has been shown to be an important asset of fertilizer application with the specific aim of increasing nutrient availability when needed. Although foliar spray of trace elements has got the majority of attention, it has been regularly observed that foliar application of macronutrients also has a positive impact on plant metabolism and ultimately on yield (Niu *et al*., 2021).

Urea is commonly used for foliar spray because of its uncharged, high solubility and it's quickly and efficiently absorbed by leaves. Foliar application of urea has been found effective in increasing the nitrogen availability to developing seeds in pulses (Palta *et al*., 2005). Foliar application of urea in adequate concentration encourages their utilization when needed and thereby maintains a steady reaction of photosynthesis. In contrast, higher concentrations may cause leaf injury and may damage the entire plant. Therefore, it is necessary to find out the adequate concentration and appropriate time of foliar spraying of nutrients for increasing their performance.

Keeping these facts into consideration the present investigation entitled **"Effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** was carried out with following objectives:

1. To study the effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil under guava based agri-horti system.
2. To work out the economics of the treatments.

Chapter II

REVIEW OF LITERATURE

The relevant literature pertaining to different aspects of present research entitled **"Effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** has been reviewed under following headings:

2.1 Effect of nitrogen, phosphorus, and sulphur application on lentil

2.1.1 Effect of nitrogen, phosphorus, and sulphur application on growth attributes

2.1.2 Effect of nitrogen, phosphorus, and sulphur application on yield attributes and yield

2.2 Effect of concentrations of urea as foliar spray on lentil

2.2.1. Effect of concentrations of urea as foliar spray on growth attributes

2.2.2 Effect of concentrations of urea as foliar spray on yield attributes and yield

2.3 Economics

2.1 Effect of nitrogen, phosphorus, and sulphur application on lentil

2.1.1 Effect of nitrogen, phosphorus, and sulphur on growth attributes

Shubhashree *et al.* (2011) conducted a field experiment at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on black clay soil to study the "Response of rajmash (*Phaseolus vulgaris* L.) to the levels of nitrogen, phosphorus, and potassium during *Rabi* season in the Northern Transition Zone" with three levels of nitrogen (40, 80 and 120 N kg ha^{-1}), three levels of phosphorus (25, 50 and 75 P_2O_5 kg ha^{-1}), and two levels of potassium (30 and 60 K_2O kg ha^{-1}) with absolute control. Significantly higher plant height, number of branches $plant^{-1}$, leaf area index, and total dry matter production was recorded with treatments of 80 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1}, and 30 kg K_2O ha^{-1}.

Kumar *et al.* (2011) investigated the effect of phosphorus (0, 20, 40, and 60 kg ha^{-1}) and sulphur (0, 20, and 40 kg ha^{-1}) on growth and nodulation of garden pea (*Pisum sativum* L.) during the *Rabi* season of 2009-10. Results revealed that the application of phosphorus and sulphur increased the growth attributes and nodulation of a garden pea. The highest plant height, number of branches $plant^{-1}$, and root nodules were observed when treated with 60 kg P_2O_5 ha^{-1} and 40 kg sulphur ha^{-1}.

Yadav (2011) investigated the phosphorus and sulphur interaction on cluster beans in a sandy loam soil rich in P but low P at Udaipur. Three levels of P (0, 20, and 40 kg ha^{-1}) and three levels of S (0, 10, and 20 kg ha^{-1}) from gypsum and triple SSP, respectively, were used in the treatment. As P and S levels increases in varying combinations, the number and weight of nodules, and P and S contents also increased.

Niraj and Prakash (2015) used a Randomized Block Design to repeat 16 treatments 3 times. As a test crop, Pant urd-35, a black gram cultivar, was used. The results revealed that phosphorus @ 45kg ha^{-1} and sulphur @ 30kg ha^{-1} significantly increased plant height, number of branches $plant^{-1}$, and dry matter accumulation $plant^{-1}$.

Kakon *et al*. (2016) carried out a field experiment during *Rabi* (winter) seasons of 2010-11 and 2011-12 at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur to study the effects of nitrogen and phosphorus on growth and yield of french bean. A randomized complete block design was followed with 10 combinations of N (0, 50, 100, 150, and 200 kg N ha^{-1}) and P (0, 22, 33, 44, and 55 kg ha^{-1}) along with a blanket dose of control. All the treatments showed that the LAI, dry matter production, CGR, and NAR significantly increased with the increase in nitrogen and phosphorus level up to 150 kg N and 44 P kg ha^{-1} respectively.

Kumar *et al*. (2017) conducted a research on effects of varying phosphorus, sulphur, and cultivars on chickpea (*Cicer arietinum* L.) growth during the *Rabi* season of 2013–14 at the Crop Experimental Farm, Department of Agronomy, Allahabad School of Agriculture, SHIATS, Allahabad, Uttar Pradesh. A 3 × 3 m (9 m) plot was used to test three phosphorus levels (40, 60, and 80 kg ha^{-1}), three sulphur levels (15, 20, and 25 kg ha^{-1}), and two cultivars (Pusa-362 and Radhey). The Pusa-362 + P_2O_5 @ 60 kg ha^{-1} + sulphur @ 25 kg ha^{-1} treatment resulted in the highest plant height (48.60

cm), number of branches plant^{-1} (7.66), number of nodules plant^{-1} (58.23), dry weight plant^{-1} (7.93 g).

Bunker *et al*. (2018) conducted an experiment during *Rabi* season in the year 2017-18 at Instructional farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner to study the effects of nitrogen, phosphorus, and bio-fertilizers on growth attributes of Garden Pea (*Pisum sativum* L.) cv. Arkel A significantly increases in the growth attributes recorded with the application of 20 Kg ha^{-1} N + 40 kg ha^{-1} P + Rhizobium + PSB over control but was at par with the application of 20 Kg ha^{-1} N + 40 kg ha^{-1} P + Rhizobium and 20 Kg ha^{-1} N + 40 kg ha^{-1} P + PSB.

Dwivedi & Dwivedi (2018) investigated the impacts of P, S, and biofertilizers on lentil growth during the *Rabi* seasons of consecutive years, 2015-16 and 2016-17 on the PL-5 variety of lentil. Plant height, number of branches plant^{-1} are increased at levels with 60 kg P ha^{-1} and 30 kg S ha^{-1}, and seed inoculation with *Rhizobium* + PSB biofertilizers.

Singh *et al*. (2018) conducted a field experiment at Narendra Deva University of Agriculture and Technology, Faizabad (UP) during *Rabi* season for two consecutive years 2014-15 and 2015-16 in chickpea. The experiment was laid out in a split-plot design having 24 treatment combinations consisting of three phosphorus levels (0, 30, 60 kg P_2O_5 ha^{-1}), two sulphur levels (0, 20 kg S ha^{-1}), and four seed inoculation with biofertilizers (un-inoculated, PSB, *Rhizobium* and PSB + *Rhizobium*). The application of phosphorus @ 60 kg ha^{-1}, sulphur @ 20 kg ha$^{-1,}$ and seed inoculation with PSB + *Rhizobium* significantly increased the dry matter plant^{-1} and number of nodules plant^{-1} in chickpea over control/un-inoculated of chickpea.

Parry *et al.* (2018) conducted a field experiment at Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad during the *Kharif* season in the year 2010 in a randomized complete block design with 12 treatment combinations consisting of three levels of nitrogen (0, 20, and 40 kg N ha^{-1}) and four levels of Sulphur (0, 20, 40 and 60 kg S ha^{-1}) replicated three times. Treatment combination N_{40} S_{60} (40 kg N ha^{-1} + 60 kg S ha^{-1}) recorded significantly higher values for plant height (65.6 cm), number of leaves plant^{-1} (32.4), fresh weight plant^{-1} (48.4 g), dry weight plant^{-1} (16.5 g), and number of nodules plant^{-1} of chickpea.

Parashar *et al.* (2020) conducted an experiment at Gwalior, Madhya Pradesh, in which 12 treatment combinations were investigated, including 4 phosphorus levels (0, 20, 40, and 60 kg ha^{-1}) and 3 sulphur levels (0, 20, and 30 kg ha^{-1}). The results revealed that significantly higher plant height, number of branches plant^{-1}, number of leaves plant^{-1}, and number of nodules plant^{-1} of black gram was recorded with combined application of phosphorus @ 60 kg ha^{-1} and sulphur @ 30 kg ha^{-1}.

2.1.2 Effect of nitrogen, phosphorus and sulphur on yield attributes and yield

Subhashree *et al.* (2011) performed an experiment at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on black clay soil to study the "Response of rajmash (*Phaseolus vulgaris* L.) to the levels of nitrogen, phosphorus, and potassium during *Rabi* season in the Northern Transition Zone" with three levels of nitrogen (40, 80 and 120 N kg ha^{-1}), three levels of phosphorus (25, 50 and 75 P_2O_5 kg ha^{-1}), two levels of potassium (30 and 60 K_2O kg ha^{-1}) with absolute control. A significantly higher number of pods plant^{-1}, seeds pod^{-1}, 100- seed weight, and seed yield was recorded with 80 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1}, and 30 kg K_2O ha^{-1}.

Akter *et al.* (2013) tested the influence of phosphorus (0, 15, 30, 50 kg ha^{-1}) and sulphur (0, 10, 20, 40 kg ha^{-1}) on soybean yield at the Sher-e-Bangla Agricultural University Farm in Dhaka, Bangladesh (*Glycine max* L.). Individual applications of various quantities of phosphorus and sulphur considerable increases in yield attributes and yield. The combination of 30 kg phosphorus ha^{-1} and 20 kg sulphur ha^{-1} resulted in the highest number of pods plant^{-1} (30.07), number of seeds pod^{-1} (84.94), 1000 seed weight (94.61 g) and grain yield (2.3 t ha^{-1}). As a result, a combined treatment of 30 kg phosphorus ha^{-1} and 20 kg sulphur ha^{-1} may be beneficial for increasing soybean production.

Choubey *et al*. (2013) laid out an experiment in Azamgarh, during the *Rabi* seasons of 2010-11 and 2011-12, on lentil in a silty loam soil. The combined treatments of phosphorus and sulphur recorded higher value of yield attributes, and seed yield when compared to the other treatments. The treatment of 60 kg P ha^{-1} and 40 kg S ha^{-1}

increased yield attributes, and seed yield, resulting in the highest yield in Eastern U.P. conditions.

Kumawat *et al.* (2014) performed a field experiment to investigate the effects of sulphur and phosphorus on the yield of summer green gram [*Vigna radiata* (L.)] during the *Kharif* season. The highest number of pods $plant^{-1}$ (20.47), the weight of 1000 seeds (4.07 g), seed yield (819 kg ha^{-1}), and stover yield (1551 kg ha^{-1}) were found when 60 kg P ha^{-1} and 30 kg S ha^{-1} was applied individually. The combined application of 60 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1} resulted in greater grain yield (937 kg ha^{-1}) and stover yield (1853 kg ha^{-1}).

Niraj and Prakash (2015) used Randomized Block Design to repeat 16 treatments 3 times. As a test crop, Pant urd-35, a black gram cultivar, was used. The results revealed that phosphorus @ 45kg ha^{-1} and sulphur @ 30kg ha^{-1} was most successful in improving yield and yield attributes such as number of pods $plant^{-1}$, number of grains pod^{-1}, test weight, grain yield, and stover yield.

Sipai *et al.* (2016) investigated the effects of P, S, and *Rhizobium* on mung bean yield attributes and nodulation in loamy sandy soil at Kutch, Gujarat. Three P_2O_5 levels (0, 20, 40 kg ha^{-1}), three S levels (0, 20, 40 kg ha^{-1}), and two *Rhizobium* levels (inoculated and uninoculated). When compared to the control, the application of 40 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1}, together with *Rhizobium* inoculation, improved significantly the yield attributes and yield of mung beans and also improved nodulation.

Rani and Prakash (2017) examined the impact of phosphorus (0, 20, 40, and 60 kg ha^{-1}), sulphur (0, 20, and 40 kg ha^{-1}), and PSB on yield attributes of *Vigna radiata*. The number of pods $plant^{-1}$, number of grains pod^{-1}, grain yield, and stover yield all significantly increase with an increase in phosphorus and sulphur levels up to 60 kg ha^{-1} and 40 kg ha^{-1}, respectively. An improved number of pods $plant^{-1}$, number of grains pod^{-1}, grain yield, and stover yield were seen when the seed was inoculated with PSB.

Sunday and Asabar (2018) performed an experiment at the National Root Crop Research Institute experimental farm Vom Plateau State, Nigeria during *Kharif* seasons (2015, 2016, and 2017) to study the response of field pea yield and its attributes to the application of different doses of nitrogen and phosphorus fertilizers. The results revealed that the higher number of pods, number of grains, and seed yield recorded with the application of 40 kg P ha^{-1} and 30 kg N ha^{-1} over other treatments.

Dwivedi & Dwivedi (2018) investigated the impacts of P, S, and biofertilizers on lentil yield attributes and yield during the *Rabi* seasons for two consecutive years, 2015-16 and 2016-17 on the PL-5 variety of lentil. Number of pods $plant^{-1}$, number of grains pod^{-1}, 1000-grain weight, and grain yield are increased at levels with 60 kg phosphorus ha^{-1} with 30 kg sulphur ha^{-1}, and seed inoculation with *Rhizobium* + PSB biofertilizers.

Singh *et al*. (2018) conducted a field experiment at the Narendra Deva University of Agriculture and Technology, Faizabad (UP) during *Rabi* season for two consecutive years 2014-15 and 2015-16 in chickpea. The experiment was layout in a split-plot design having 24 treatment combinations consisting of three phosphorus levels (0, 30, 60 kg P_2O_5 ha^{-1}), two sulphur levels (0, 20 kg S ha^{-1}), and four seed inoculation with biofertilizers (un-inoculated, PSB, *Rhizobium* and PSB + *Rhizobium*). The application of phosphorus @ 60 kg ha^{-1}, sulphur @ 20 kg $ha^{-1}$and seed inoculation with PSB + *Rhizobium* significantly increased the grain yield and stover yield in chickpea over control/un-inoculated of chickpea.

Singh *et al*. (2018) conducted an experiment which was laid out in a double split-plot design with three replications accommodating 24 treatments combination consisted four levels of nitrogen (30, 60, 90 & 120 kg ha^{-1}), three levels of phosphorus (0, 30 & 60 kg ha^{-1}) and two levels of sulphur (15 & 30 kg ha^{-1}). In this experiment Rajmash variety, HUR-15 was selected as the test crop. The results revealed that nitrogen @ 120 kg ha^{-1}, phosphorus @ 60 kg ha^{-1}, and sulphur @ 30 kg ha^{-1} recorded significantly higher grain yield.

Pandey *et al.* (2019) a research study was conducted during the *Rabi* season of 2016-17 and 2017-18 on loamy soil at Kulbhashkar Ashram P.G. College Farm in Allahabad to determine the impact of phosphorus (0, 40, 60, and 80 kg P_2O_5 ha^{-1}) and sulphur (0, 30, and 60 kg S ha^{-1}) treatment on yield attributes and yield of lentil. Yield and yield attributes of lentil increased with every incremental dose of phosphorus and sulphur, up to the highest level of phosphorus and sulphur used but significant increase was registered at 60 kg P_2O_5 ha^{-1} and 30 kg S ha^{-1}.

Usha *et al*. (2019) performed a field experiment to study the effect of nitrogen and sulphur on the growth and yield of French beans. The experiment consisted of two factors namely i.e. nitrogen levels (0, 60, 90, 120, and 150 kg N ha^{-1}) and sulphur levels (0, 10, 15, and 20 kg S ha^{-1}). Considering the interactions it was found that the yield attributes and yield of french bean varieties were increased with a good combination of nitrogen and sulphur doses. They concluded that the highest grain yield was observed in 120 kg N ha^{-1} × 10 kg S ha^{-1}, whereas the lowest grain yield was found in 0 kg N ha^{-1} × 15 kg S ha^{-1}.

Parashar *et al.* (2020) laid out a field experiment at Gwalior, M.P., in which 12 treatment combinations were investigated, including 4 phosphorus levels (0, 20, 40, and 60 kg ha^{-1}) and 3 sulphur levels (0, 20, and 30 kg ha^{-1}). The significantly higher grain and stover yield ha^{-1} of black gram was recorded with the application of phosphorus @ 60 kg ha^{-1} with sulphur @ 30 kg ha^{-1}.

2.2 Effect of concentrations of urea as foliar spray on lentil

2.2.1 Effect of concentrations of urea as foliar spray on the growth attributes

Ali and Kumar (2006) found that the beneficial effect of foliar application of 2% urea solution at the reproductive stage i.e., flowering and pod formation in most of the pulse crops such as chickpea, and pigeon pea.

Verma *et al.* (2009) conducted an experiment at Kanpur, to study the effect of 3 concentrations of urea@ 0.25, 0.50, and 1% as foliar spray at 45 and 65 DAS against control on three chickpea genotypes namely KDG-1168, Udai and Awarodhi during *Rabi* 2005-06 and 2006-07 under rainfed condition. The results revealed that plant height significantly improved up to 1% urea concentrations and number of branches $plant^{-1}$ showed significant increase only up to 0.5% urea concentrations at 45 and 65 DAS.

Venkatesh and Basu (2011) conducted during two consecutive *Rabi* seasons of 2006-07 and 2007-08 on inceptisol soil at Indian Institute of Pulses Research (IIPR) in Kanpur, found that foliar spraying of 2% urea at 60, 75, and 90 DAS produced a higher number of branches $plant^{-1}$ (5.9) and was statistically comparable to one or two urea sprays, but it’s much higher than the control and water spray in chickpea.

Venkatesh *et al.* (2012) conducted an experiment at Indian Institute of Pulses Research (IIPR) in Kanpur, found that foliar spraying chickpea with 2% urea at 75 DAS resulted in a higher number of branches plant^{-1} (6.93), which was statistically comparable to 2% DAP spray at 75 DAS but significantly higher than control and water spray. Foliar application of 2% urea at 75 + 105 DAS raised plant dry weight significantly more than other treatments in chickpea.

Sengupta and Tamang (2015) conducted a field experiment on the Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal during the summer season of 2010 and 2011 on sandy loam alluvial soil in green gram. The experiment was carried out in RBD with 8 treatments and 3 replications and found that foliar application of 2% urea and 2% DAP had improved the plant height, dry matter accumulation, and LAI of Bireshwar variety of green gram.

Das and Jana (2016) conducted a field experiment at Pulses and Oilseeds Research Station, Berhampore, Murshidabad, West Bengal during the *Rabi* season 2007-08, 2008-09, and 2009-10 to study the effects of urea spray in lentil. The experiment was conducted in Factorial Randomized Block Design with four replications and 10 treatments and the results revealed that the growth attributes such as plant height, number of branches plant^{-1}, and dry matter plant^{-1} of lentil were significantly increased by 2% urea spray.

Kumari (2017) found that foliar application of urea at 2% + salicylic acid at 75ppm spray, combined with RDF, resulted in increased growth attributes such as plant height, number of branches plant^{-1}, and dry matter accumulation plant^{-1} of green gram.

Kobir *et al.* (2020) conducted a field experiment at the Regional Agricultural Research Station, Jashore, Bangladesh during the *Rabi* season of 2019-2020 to study the effect of foliar application of urea on growth of short durative lentil variety (BARI Masur-9). The experiment was laid out in a split-plot design with foliar application of urea and the results revealed that the highest plant height was found with the application of 75% of urea with 100% of other fertilizers as basal and the rest of 25% of urea spraying at the pod initiation stage.

Singh *et al*. (2022) conducted an experiment at 5 different locations in Punjab, India, to investigate the impact of foliar application of urea on growth attributes of chickpea grown under irrigated conditions. In the experiment, foliar applications of 2% urea were made at various phases of flowering, pod formation, both stages (flowering and pod formation), and control. The maximum number of root nodules plant^{-1}, dry matter accumulation plant^{-1}, and plant height were observed by application of 2% urea during the blooming or flowering and pod formation stages.

2.2.2 Effect of concentrations of urea as foliar spray on the yield attributes and yield

Dudhado *et al.* (2003) performed an experiment at Rahuri, Maharashtra, and found that foliar spraying of chickpea with 2% KCl at 30 and 40 DAS increased grain yield as compared to control and water spray, but was significantly less effective than spraying with 2% urea and 2% DAP.

Palta *et al.* (2005) found that foliar treatment of 2% urea spray at blooming and pod development stages increased productivity and total biomass of chickpea.

Kumar *et al.* (2008) from Coimbatore, Tamilnadu, found that a 1% urea spray at flower initiation and 15 days thereafter resulted in a much higher seed yield of black gram than the other treatments, but was on par with 2% DAP spray.

Verma *et al.* (2009) conducted an experiment at Kanpur, to study the effect of 3 concentrations of urea@ 0.25, 0.50, and 1% as a foliar spray at 45 and 65 DAS against control on three chickpea genotypes namely KDG-1168, Udai and Awarodhi during *Rabi* 2005-06 and 2006-07 under rainfed condition. The results revealed that the 1000 seed weight, harvest index, and seed yield significantly improved up to 1% urea concentration at 45 and 65 DAS.

Yadav and Chaudhary (2011) conducted an experiment during *Kharif* season of 2009 on loamy sand soil at Jobner, Rajasthan. They reported that 2% DAP spray significantly increased seed yield in cowpea during the branching and blooming stages compared to water spray and control, however, 2% urea and 2% KCL spray had similar results.

Venkatesh and Basu (2012) laid out an experiment to study the response of chickpea on foliar application of urea at Indian Institute of Pulses Research (IIPR) in Kanpur, Uttar Pradesh, and reported that foliar spraying of 2% urea at 75 DAS resulted in increased pods per plant^{-1} (45.3), which were 23.7 and 21.3 % higher than control and water spray, respectively. The highest seed yield (2437 kg ha^{-1}) was recorded with 2% urea spray followed by 2% DAP spray (2389 kg ha^{-1}).

Bhowmick (2013) conducted an experiment at the Pulses and Oilseeds Research Sub-station, Beldanga, Murshidabad, West Bengal found that foliar spraying 2% urea twice at flowering and 10 days later significantly enhanced grain yield of chickpea over no spray and water spray.

Kumawat and Mahla (2015) conducted an experiment at Jaisalmer, Rajasthan during two consecutive *Kharif* seasons of 2010 and 2011 to evaluate the effect of 1% urea on yield attributes and yield of cluster bean under rainfed conditions. The results revealed that the grain yield and harvest index increased by 83% and 13% respectively with dual application of 1% urea on crop foliage at 30 and 50 DAS.

Sengupta and Tamang (2015) conducted a field experiment on the Farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal during the *Kharif* season of 2010 and 2011 on sandy loam alluvial soil. This experiment was carried out in RBD with 8 treatments and 3 replications and found that foliar application of 2% urea and 2% DAP at 25 and 45 DAS had increased the number of pods plant^{-1}, number of grains pod^{-1}, and seed yield of Bireshwar variety of green gram.

Das and Jana (2016) conducted a field experiment at Pulses and Oilseeds Research Station, Berhampore, Murshidabad, West Bengal during the *Rabi* season 2007-08, 2008-09, and 2009-10 to study the effects of urea spray in lentil. The experiment was conducted in a Factorial Randomized Block Design with 4 replications and 10 treatments and the result revealed that yield attributing characters and yield such as number of pods plant^{-1}, number of grains pod^{-1}, and grain yield of lentil were significantly increased by urea spray.

Kumari (2017) found that foliar application of urea @ 2% + salicylic acid @ 75ppm spray, combined with RDF, resulted in an increase in seed yield, and stover yield of green gram.

Dey *et al.* (2017) found that foliar sprays of 2% urea followed by 2% KCl during flowering and 15 days after flowering significantly improved yield attributes and yield of cowpea.

Kobir *et al.* (2020) conducted a field experiment at the Regional Agricultural Research Station, Jashore, Bangladesh during the *Rabi* season of 2019-2020 to study the effect of foliar application of urea on the yield of short durative lentil variety (BARI Masur-9). The experiment was conducted in a split-plot design with different concentrations of urea as a foliar spray and the results revealed that the highest number of pods plant^{-1} and seed yield were found from the application of 75% of urea with 100% of other fertilizers as basal and the rest 25% of urea spraying at the pod initiation stage.

Pal *et al*. (2020) investigated the effects of foliar application of urea on yield attributes and grain yield in chickpea. The highest yield attributes and grain yield (1939 kg ha^{-1}) were obtained with foliar application of 2% urea at flowering + pod formation stages. These results were statistically similar to foliar application of 2% urea at flowering stage alone.

Jaybhay *et al*. (2021) carried out an experiment during the *Kharif* season of 2016 and 2017 at MACS Agharkar Research Institute, Pune, India to study the influence of foliar application of urea on yield attributes and yield of soybean crop. The results revealed that the application of RDF + Urea 2% (3098 kg ha^{-1}) gives significantly higher grain yield over control (2704 kg ha^{-1}) and RDF + water spray (2686 kg/ha) but was at par with RDF + DAP 2% (3050 kg ha^{-1}).

Singh *et al*. (2022) conducted an experiment at 5 different locations in Punjab, India, to investigate the impact of foliar application of urea on growth attributes of chickpea grown under irrigated conditions. In the experiment, foliar applications of 2% urea were made at various phases of flowering, pod formation, both stages (flowering and pod formation), and control. The results revealed that the foliar application of urea at both stages (flowering as well as pod formation) improved the grain yield by 19.3% over control.

2.3 Economics

Gupta *et al*. (2011) found that the foliar application of 2% urea in chickpea at flowering and 10 DAS along with bio-fertilizers resulted in higher net return (₹ 5608 ha^{-1}) over control which was attributed to enhanced grain yield.

Akter *et al*. (2011) evaluated the seed yield of chickpea (*Cicer arietinum* L.) in response to the application of various levels of phosphorus (0, 40, and 80 kg P_2O_5 ha^{-1}) and sulphur (0, 15 & 30 kg S ha^{-1}). The economic analysis demonstrated that the benefit-cost ratio was less than 2 for higher levels of phosphorus either alone or in combination with sulphur. Production of chickpeas was found to be more economical and cost-effective if using the $P_{40}S_{30}$ combination.

Subhashree *et al.* (2011) an experiment was performed at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad on black clay soil to study the "Response of rajmash (*Phaseolus vulgaris* L.) to the levels of nitrogen, phosphorus, and potassium during *Rabi* season in the Northern Transition Zone" with three levels of nitrogen (40, 80 and 120 N kg ha^{-1}), three levels of phosphorus (25, 50 and 75 P_2O_5 kg ha^{-1}), two levels of potassium (30 and 60 K_2O kg ha^{-1}) with absolute control (0:0:0 N:P:K kg ha^{-1}). Significantly higher net returns (₹ 21113 ha^{-1}) and benefit-cost ratio (2.72) was also obtained with application of 80 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1}, and 30 kg K_2O ha^{-1}.

Choubey *et al*. (2013) conducted an experiment at Azamgarh, Uttar Pradesh during the *Rabi* seasons of 2010-11 and 2011-12, on silty loam soil. On the basis of economics application of 60 kg phosphorus ha^{-1} along with 40 kg sulphur ha^{-1} best net return and benefit-cost ratio of lentil variety Narendra Masoor-2.

Sipai *et al.* (2016) investigated the effects of P, S, and *Rhizobium* on mung bean yield attributes and nodulation in loamy sandy soil at Kutch, Gujarat. Three P_2O_5 levels (0, 20, 40 kg ha^{-1}), three S levels (0, 20, 40 kg ha^{-1}), and two *Rhizobium* levels (inoculated and uninoculated). When compared to the control, the application of 40 kg

P_2O_5 and 40 kg S ha^{-1}, together with *Rhizobium* inoculation, produced the highest gross and net returns, as well as a B: C ratio of 6.73:1.

Shreenivas *et al.* (2017) studied the effect of nutrient management on productivity, soil fertility, nutrient uptake, and economics of maize-chickpea cropping sequence during the *Kharif* and *Rabi* seasons of 2013-14 and 2014-15. The cost of cultivation of maize-chickpea sequence was higher (₹ 50,542 ha^{-1}) with nutrients applied through a 125% Site specific nutrient management (SSNM) approach for a targeted yield of 8.0 tonne ha^{-1}. However, the higher maize-equivalent yield, gross returns, net returns, and benefit-cost ratio (19083 kg ha^{-1}, ₹ 2,53,985, ₹ 2,04,279 ha^{-1}, and 5.11, respectively) could be achieved in Site specific nutrient management (SSNM) approach targeted yield of 8.0 tonne ha^{-1}.

Singh *et al.* (2018) conducted a field experiment at the Crop Research Centre of the Department of Agriculture, Sahib, during the *Kharif* season in the year 2015 to study the impacts of phosphorus and sulphur on yield, yield attributes, and also on economics of chickpea. Based on economics, 60 kg P_2O_5 ha^{-1} application was superior to 40 kg P_2O_5 $ha^{-1,}$ and 40 kg S ha^{-1} was superior to 30 kg S ha^{-1}. The calculations showed that $P_{60}S_{40}$ had the highest cost of cultivation (₹ 28930), net return (₹ 38210), and benefit-cost ratio (2.32) of all the treatments.

Kumar *et al.* (2017) conducted research on the effects of varying phosphorus, sulphur, and cultivars on chickpea growth and economics during the *Rabi* season of 2013–14 at the Crop Experimental Farm, Department of Agronomy, Allahabad School of Agriculture, SHIATS, Allahabad, Uttar Pradesh (*Cicer arietinum* L). A 3 × 3 m ($9m^2$) plot size was used to test three phosphorus levels (40, 60, and 80 kg ha^{-1}), three sulphur levels (15, 20, and 25 kg ha^{-1}), and two cultivars (Pusa-362 and Radhey). The Pusa-362 + P2O5 60 kg ha^{-1} + sulphur 25 kg ha^{-1} treatment resulted in the highest gross return (₹ 107790), net return (₹ 84342.72), and benefit-cost ratio (4.59).

Rani and Prakash (2017) examined the impact of phosphorus (0, 20, 40, and 60 kg ha^{-1}), sulphur (0, 20, and 40 kg ha^{-1}), and PSB on the economics of *Vigna radiata*. It was found that net return increased as phosphorus, sulphur, and seed inoculation with PSB levels increased.

Dwivedi & Dwivedi (2018) investigated the impacts of P, S, and biofertilizers on lentil growth, yield, and economics during the *Rabi* seasons for two consecutive years, 2015-16 and 2016-17 on the PL-5 variety of lentil. P60, S30, and *Rhizobium* + PSB produced increased net returns of ₹ 8689, ₹ 2643, and ₹ 3237 ha^{-1}, respectively, over their respective controls.

Pal *et al*. (2020) investigated the effects of foliar application of urea on economics in chickpeas. The highest net returns ($851.59 ha^{-1}), and benefit-cost ratio (1.65) were obtained with foliar application of 2% urea at flowering + pod formation stages. These results were statistically similar to foliar application of 2% urea at flowering stage alone.

Jaybhay *et al*. (2021) carried out an experiment during the *Kharif* season of 2016 and 2017 at MACS Agharkar Research Institute, Pune, India to study the influence of foliar application of urea on economics of soybean crop. The result revealed that the application of RDF + Urea 2% gives significantly higher net returns (₹ 49006 ha^{-1}) and benefit-cost ratio (2.23).

Singh *et al*. (2022) conducted an experiment at 5 locations in Punjab, India to study the effect of foliar application of urea on economics of chickpea under irrigated conditions. In the experiment, foliar applications of 2% urea were made at various phases of flowering, pod formation, both stages (flowering and pod formation), and control and the results revealed that the foliar application of urea at both stages (flowering as well as pod formation) increased net monetary returns by 30.4% as compared to control.

Chapter III

MATERIALS AND METHODS

The present investigation entitled **"Effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** was conducted at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Varanasi (Uttar Pradesh) during *Rabi* (winter) season of 2021-2022. The detailed information on location, edaphic and climatic conditions of the experimental site under which the crop was raised along with material and methods employed are described in this chapter.

3.1 Location of the experimental site

The experiment was carried out at Agricultural Research Farm, Rajiv Gandhi South Campus, Barkachha situated in eastern Uttar Pradesh of district Mirzapur, during *Rabi* season of 2021-22. The Vindhyan region comes under rainfed conditions where different agricultural, horticultural, and medicinal plants are cultivated covering an area of more than 1000 hectares. Geographically, the area of the Agricultural Research Farm comes under climatic zone III A (Semi-arid eastern plain zone) and it is located at a distance of 10 km southeast direction from Mirzapur.

3.2 Climate and weather during crop period

Usually, the climatic condition of Barkachha, Mirzapur (U.P) is semi-arid to sub-humid with moderate humidity (60-70%) and very low precipitation. The seasons distinct, summer are too hot and winters are too cool. Weather parameters during the field experimentation are given in Table 3.1 and also graphically represented in Figure 3.1.

3.2.1 Rainfall (mm)

Total amount of rainfall received during the period of crop growth was 31.2 mm. The maximum amount of rainfall was observed during January (10.9 mm).

Table 3.1: Mean weekly meteorological data during *Rabi* season (Oct. 2021- 2022 Mar)

Standard week no.	Month and Date	Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)		Sunshine (hours day^{-1})
			Max.	Min.	Max.	Min.	
42	Oct.20-26	00	31.2	14.8	89	23	5.6
43	Oct.27-02Nov.	00	29.4	15.1	86	24	5.9
44	Nov.03-09	00	31.1	13.2	86	23	5.8
45	Nov.10-16	5	31.2	14.1	89	23	5.6
46	Nov.17-23	00	29.5	13.3	90	35	5.3
47	Nov.24-30	00	29.8	11.4	88	23	5.4
48	Dec.01-07	00	28.2	12.2	86	26	5.4
49	Dec.08-14	00	26.2	13.4	92	25	4.2
50	Dec.15-21	6	25.1	12.2	88	29	5.4
51	Dec.22-28	00	25.5	11.5	85	19	6
52	Dec.29-04Jan.	8.6	23.2	9.3	97	23	3.1
1	Jan.05-11	1.2	24.2	11.5	93	28	3.3
2	Jan.12-18	5.4	22.5	8.3	98	57	1.6
3	Jan.19-25	00	22.2	5.5	95	26	2.2
4	Jan.26-01Feb.	00	25.8	6.6	96	32	3.4
5	Feb.02-08	4.3	25.1	7.2	91	28	7.2
6	Feb.09-15	00	24.4	7.5	88	26	5.7
7	Feb.16-22	00	22.9	8.6	91	23	9.6
8	Feb.23-01Mar.	0.3	29.2	10.3	83	16	8.7
9	Mar.02-08	0.4	29.4	11.2	90	23	8.4
10	Mar.09-15	00	32.5	12.4	81	18	9.4

Source: Meteorological Observatory of Krishi Vigyan Kendra, Mirzapur, Uttar Pradesh.

3.2.2 Temperature (⁰C)

During the crop season of 2021-22, the weekly mean maximum temperature ranged from 22.2 ^{0}C to 32.5 ^{0}C whereas the weekly minimum temperature ranged from 5.5 ^{0}C to 15.1 ^{0}C.

3.2.3 Relative Humidity (%)

During the experimental year, the weekly mean maximum relative humidity ranged from 81% to 98% while the weekly minimum relative humidity ranged from 16% to 57%.

3.2.4 Sunshine duration (hours)

During the experimental year, the weekly mean maximum sunlight duration was 9.6 hours day^{-1} whereas the weekly minimum sunlight duration was 1.6 hours day^{-1}.

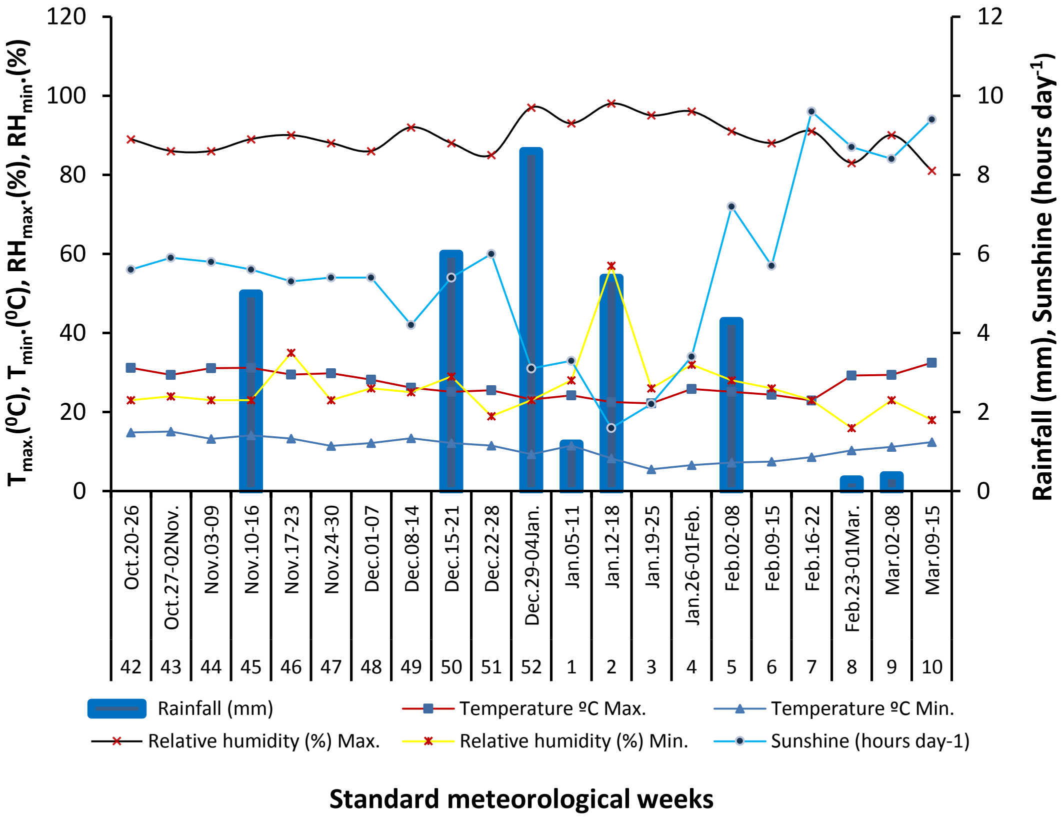

Fig. 3.1: Standard week wise mean meteorological data during *Rabi* season (Oct. 2021-2022 Mar.)

3.3 Soil

Before experimentation, undisturbed soil samples were collected from a depth of 0-20 cm with all possible precautions prescribed for soil sampling. The loose soil was collected, sealed in plastic bags, and then taken to the laboratory, where it was air-dried and crushed so that it can pass through the 2.0 mm mesh sieve. The processed samples were mixed together and a representative working sample was drawn from the composite sample. This working sample was analyzed for appropriate mechanical, physical as well as chemical properties. The results obtained from the analysis are presented in Table 3.2.

Table 3.2: Mechanical, physical and chemical properties of soil of the experimental field

Characteristic	Values obtained	Method of determination	Remarks
Mechanical Properties			
Soil Separates (%)			
Coarse sand	10.20	International pipette method (Piper, 1996)	Sandy clay loam
Fine Sand	48.16		
Silt	19.58		
Clay	21.66		
Texture class	Sandy clay loam	Textural triangle method (Black *et al*.,1965)	
Physical Properties			
Bulk density (Mg m^{-3})	1.42	Core sampler method (Black *et al*.,1965)	
Particle density (Mg m^{-3})	2.58	Pycnometer method (Black *et al*.,1965)	
Chemical properties			
pH of soil	5.44	Blackman's glass electrode method (Jackson, 1958)	Strongly acidic
Electrical Conductivity (EC) dS m^{-1} at 25^0C	0.16	Systronics Electrical Conductivity Meter (Chopra and Kanwar, 1976)	
Organic carbon (C) (%)	0.34	Walkley and Black rapid titration method (Piper, 1966)	Low
Available nitrogen (N) (kg ha^{-1})	169.20	Modified alkaline permanganate method (Subbiah and Asija, 1956)	Low
Available phosphorous (P_2O_5) (kg ha^{-1})	17.70	0.5M $NaHCO_3$ extractable (Olsen *et al*.,1954)	Medium
Available potassium (K_2O) (kg ha^{-1})	181.20	1N neutral ammonium acetate method (Piper, 1966)	Medium

The data obtained from analysis clearly revealed that the soil of the field was sandy clay loam in texture and has good drainage capacity. In addition, it strongly acidic in nature and was low in organic carbon and nitrogen.

3.4 Cropping history of the experimental field

The details of crop sequence followed in the experimental field during the last 5 years have been presented in Table 3.3. It is clear from the cropping history of the experimental field that the field was not cropped continuously and was kept barren for mostly during the *Rabi* seasons. But during 2019-20, the pigeon pea-foxtail millet sequence was followed and during 2020-21, the chickpea was grown in *Rabi* season while *Kharif* season was kept fallow.

Table 3.3: Cropping history of the experimental field

Year	***Kharif***	***Rabi***
2016-17	Pearl Millet	Fallow
2017-18	Green Gram	Fallow
2018-19	Pearl Millet	Fallow
2019-20	Pigeon pea	Foxtail millet
2020-21	Fallow	Chickpea
2021-22	Fallow	Experimental crop (Lentil)*

3.5 Experimental details

The experimental trial was conducted during *Rabi* season of 2021-22 on lentil grown in alleys of guava plantation (GP) in split plot design (SPD) comprised of 12 treatment combinations along with three replications. Each replication was divided into four main plots and each main plot was subdivided into three sub plots. The main plot treatments comprised of doses of nitrogen, phosphorus and sulphur (DNPS) $N_{0+}P_{0+}S_{0,}$ $N_{20+}P_{40+}S_{20,}$ $N_{20+}P_{50+}S_{30,}$ $N_{23.5+}P_{60+}S_{40}$ and sub plot of three concentrations of urea as foliar spray of water spray at pre-flowering stage (45 DAS), 2% urea at pre-flowering stage (45 DAS), 2% urea at pre-flowering stage (45 DAS) followed (*fb*) by 2% urea at pod initiation stage (75 DAS). The treatments were randomly allocated within main as well as in sub plots. The details of the treatment are presented in Table 3.4 and the layout is illustrated in Figure 3.2.

Table 3.4(a): Treatment combination

S. No.	Treatment	Symbols
T_1	Control (N_0+P_0+S_0) + water spray at PF*	**M_1WS**
T_2	Control (N_0+P_0+S_0) + 2% urea at PF*	**M_1US_2**
T_3	Control (N_0+P_0+S_0) + 2% urea at PF* *fb* 2% urea at PI**	**M_1US_{2+2}**
T_4	(N_{20}+P_{40}+S_{20}) + water spray at PF*	**M_2WS**
T_5	(N_{20}+P_{40}+S_{20}) + 2% urea at PF*	**M_2US_2**
T_6	(N_{20}+P_{40}+S_{20}) + 2% urea at PF* *fb* 2% urea at PI**	**M_2US_{2+2}**
T_7	(N_{20}+P_{50}+S_{30}**)** **+** water spray at PF*	**M_3WS**
T_8	(N_{20}+P_{50}+S_{30}**)** **+** 2% urea at PF*	**M_3US_2**
T_9	(N_{20}+P_{50}+S_{30}**)** **+** 2% urea at PF* *fb* 2% urea at PI**	**M_3US_{2+2}**
T_{10}	($N_{23.5}$+P_{60}+ S_{40}) + water spray at PF*	**M_4WS**
T_{11}	($N_{23.5}$+P_{60}+ S_{40}) + 2% urea at PF*	**M_4US_2**
T_{12}	($N_{23.5}$+P_{60}+ S_{40}) + 2% urea at PF* *fb* 2% urea at PI**	**M_4US_{2+2}**

* PF = Pre-flowering stage; **PI = Pod initiation stage

Table 3.4(b): Treatment details and symbols

Treatment	**Symbols**
Main plot: Doses of nitrogen + phosphorus + sulphur (kg ha^{-1})	
N_0+P_0+S_0 (Control)	**M_1**
N_{20}+P_{40}+S_{20}	**M_2**
N_{20}+P_{50}+S_{30}	**M_3**
$N_{23.5}$+P_{60}+ S_{40}	**M_4**
Subplot: Concentrations (percent) of urea as foliar spray	
Water spray at PF*	**WS**
2% urea at PF*	**US_2**
2% urea at PF* *fb* 2% urea at PI**	**US_{2+2}**

* PF = Pre-flowering stage; **PI = Pod initiation stage

Table 3.4(c): Experimental details

Design of experiment	Split plot design
Treatment (No.)	12
Replication (No.)	3
Total number of plots	36
Gross plot size	4.8 m×3 m
Net plot size	3 m× 2 m
Tree to tree spacing	7 m×7 m
Row spacing between lentil	30 cm
Plant to plant distance of lentil	5 cm
Distance between plant plot	0.5 m
Distance between replication	1 m
Seed rate	30 kg ha^{-1}

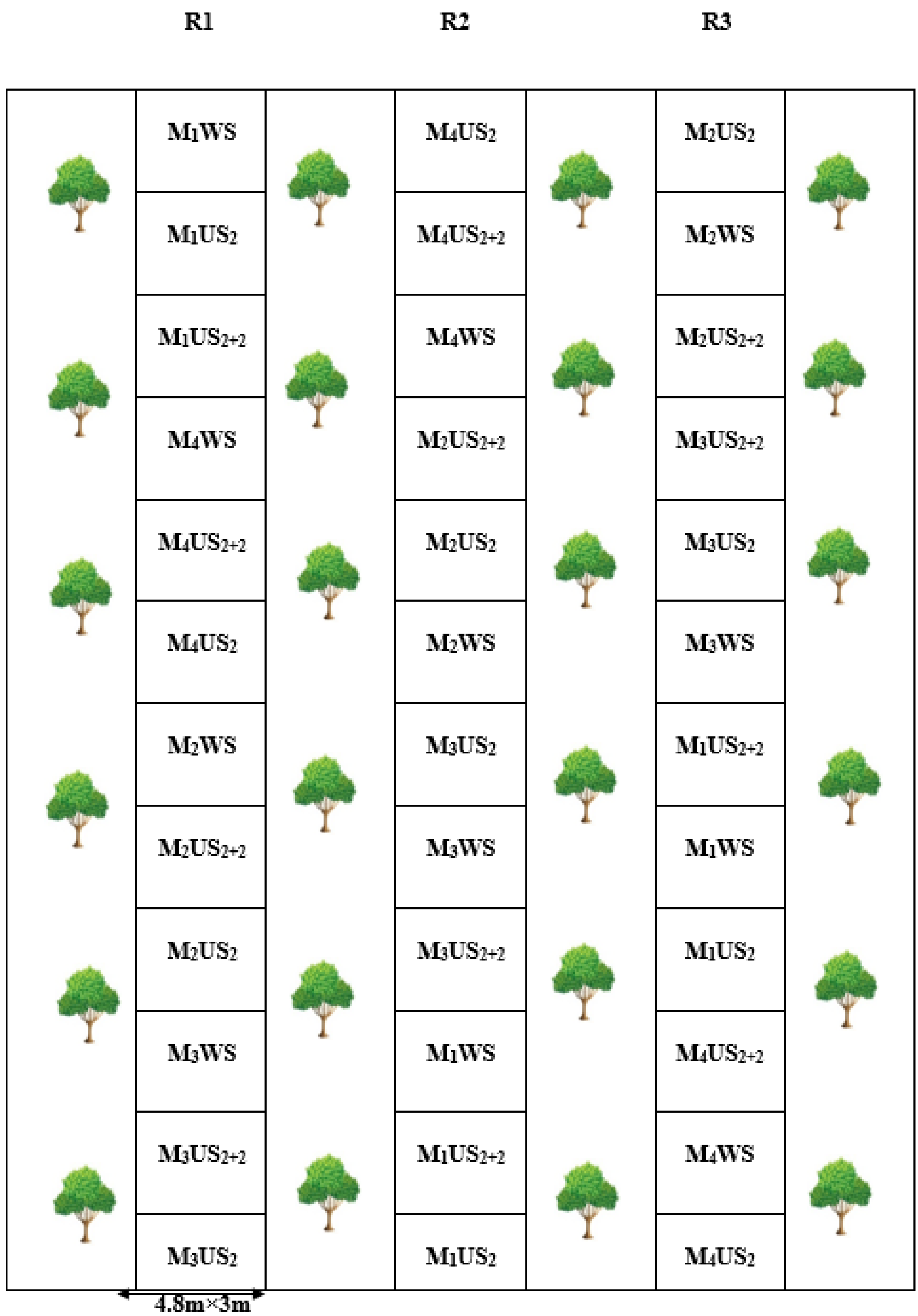

Fig. 3.2: Layout plan of the experimental field

3.6 Selection of experimental material

3.6.1 Description of agri-horti system (lentil-guava system)

The Malviya Vishwanath (HUL- 57) variety of lentil was selected for the experimental work. It was released in 2005 from BHU. The growth habitat of the variety is semi-erect with an average plant height of 34 cm. The colour of the stem is green along with dark green, a slight pubescent leaf. This variety is resistant to rust and wilt, which is small-seeded. It takes nearly 120 DAS for its maturity. The average yield of HUL- 57 variety of lentil is 1400 kg ha^{-1}.

Guava (Var. Lucknow- 49) is the common tropical fruit tree in the family Myrtaceae cultivated in tropical and subtropical regions of the world. It gives an assured return with very little care because of its hardy nature. Its production cost is also low as it requires low fertilizer as well as low plant protection. The guava trees under which lentil was grown, is popularly known as 'Sardar guava' or 'Sardar L-49'. Its selection was made at Pune. The leaves size varied from 12.5 -13.5 cm and are oval to oblong in shape. The fruits are round in shape with average fruit weight of 71.4-140 g. The trees were planted at a spacing of 7 m×7 m (L × B).

In this agri-horti system (lentil-guava system), lentil occupied 6857 m^2 (0.6857 ha) under guava plantation (GP) in 1 hectare.

3.6.2 Fertilizer application

The appropriate amount of nitrogen, phosphorus and sulphur were calculated according to the treatment combination for each plot separately and were applied just before sowing in-furrow opened by spade below 5 cm deep at a distance of 30 cm. The sown furrow was covered with soil. The source of N, P, K & S fertilizers were Urea, DAP, MOP, & sulphur WDG, respectively.

3.6.2.1 Urea

Urea is the most widely utilized nitrogen fertiliser and it's made by heating ammonia with CO_2 at a high temperature (between 160 and 170 ℃). Among solid fertilizer, urea has the highest nitrogen content (46 %). Nitrogen is present in the form of amide.

3.6.2.2 Diammonium phosphate (DAP)

DAP is a concentrated phosphate-based fertilizer. Phosphorus (46%) is an essential nutrient along with nitrogen (18%) and plays a vital role in the development of new plant tissues and the regulation of protein synthesis in crops.

3.6.2.3 Muriate of Potash (MOP)

In MOP fertilizer, K_2O is a major primary source. It is also known as potassium chloride (KCl). Sylvinite ore is used to refine MOP, while brine from carnallitic rocks is used to extract MOP. MOP contains between 60 to 61% K_2O.

3.6.2.4 Sulphur (S)

Sulphur 90% WDG is an organic nutrient rich product as per integrated nutritional management. It is a low input efficiency product to provide overall health for soil and plant. It converts to sulphate faster than other forms of elemental sulphur.

3.7 Agronomical operations

The details of all agronomical operations are presented in Table 3.5.

Table 3.5: Different agronomical operations performed during crop growth

S.No.	Operations	Date
A.	**Pre-sowing operation**	
1.	Pre-sowing irrigation	26/10/2021
2.	Land preparation	
	➢ First ploughing by soil turning plough	29/10/2021
	➢ Second ploughing by cultivator	30/10/2021
3.	Layout	30/10/2021
B.	**Sowing operation**	
	➢ Sowing of lentil	31/10/2021
C.	**Fertilizer application**	
	➢ Full doses K_2O were applied at sowing time	31/10/2021
	➢ Nitrogen, Phosphorus and Sulphur was applied as per treatment at sowing time	31/10/2021
D.	**Irrigation**	
	➢ First irrigation	15/12/2021
	➢ Second irrigation	18/01/2022
E.	**Intercultural operation**	
	➢ First weeding	01/12/2021
	➢ Second weeding	21/12/2021
F.	**Harvesting**	01/03/2022
G.	**Threshing**	08/03/2022
H.	**Cleaning**	09/03/2022

3.7.1 Land preparation

The land was prepared by ploughing once with the help of tractor-driven disc plough. Thereafter the field was cross harrowed twice followed by planking in order to level the soil and to obtain a fine tilth. Thereafter, according to plan and design layout was prepared.

3.7.2 Seed rate and sowing

Viable and healthy seeds were collected for the sowing of the experimental crop. Lentil (variety HUL-57) was manually sown in the furrow with the help of *Kudal* at a row spacing of 30 cm and at a depth of 3-4 cm. Relatively, higher seed rate (30 kg ha^{-1}) was used for proper maintenance of plant population.

3.7.3 Weeding

Manual hand weeding was done 2 times with the help of *Khurpi*. The first weeding was done at 30 DAS and the second weeding at 50 DAS.

3.7.4 Irrigation

Irrigation was applied to the crop in order to keep the field moist. Two irrigations were applied at 45 DAS and 75-80 DAS.

3.7.5 Harvesting

The crop was harvested after judged by visual observations i.e., physiological maturity. The crop was harvested separately from each plot. Thereafter, the produce from the net plot was tied into bundles separately and then tagged. The tagged bundles were allowed for sun drying in the field and after sun drying, the weight of bundles was recorded for obtaining biological yield.

3.7.6 Threshing

Treatment-wise threshing of lentil crop was done manually by beating plants on the sheet with wooden batons and then seeds were separated by winnowing. Caution was taken so as to prevent the mixing of grains between the treatments.

3.8 Biometric observation

A technique of random sampling was adopted for recording the observations of plant on the various parameters of the test crop. Five plants from each plot were selected randomly for the observation to record at different parameters at successive stages of growth. The observations on the growth parameters were recorded at 30, 60 and 90 DAS and at harvest stage. Yield attributes and yield were recorded after harvesting of test crop.

3.8.1 Growth attributes

3.8.1.1 Plant height (cm)

The height of the randomly tagged 5 plants of lentil was measured from the ground level to the tip of the main shoot. Plant height was recorded at 30, 60, 90 DAS and at harvest stage. The average plant height of lentil was calculated for each plot by taking the mean of 5 observation and were expressed in cm.

3.8.1.2 Number of branches plant^{-1}

A number of branches of randomly tagged 5 plants from each plot was counted and the average number of branches plant^{-1} was recorded at 30, 60, 90 DAS and at harvest stage.

3.8.1.3 Number of green leaves plant^{-1}

A number of green leaves of randomly tagged 5 plants from each plot was counted and the average number of green leaves plant^{-1} was recorded at 30, 60, 90 DAS.

3.8.1.4 Root nodules plant^{-1}

Number of root nodules plant^{-1} were recorded by averaging 5 plants randomly tagged from each plot at 30 and 60 DAS. Uprooted roots were cleaned after loosening the soil surrounding in the root zone area of respective plants from each plot of destructive rows with the help of *Khurpi*. Further, the plants were kept in water to discard the soil adhered to roots. With the help of a scalpel, the nodules were excised and then counted and expressed as the number of root nodules plant^{-1}.

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

To record the dry matter accumulation at 30, 60, 90 DAS and harvest stage, 5 plants were randomly selected and uprooted from destructive rows of each plot. Root portions were removed and the shoot portion of each plot were kept in an envelope and were partial sun-dried for a few days. After partial sun drying, selected sample were subjected to hot air oven at 70°C for 24 hours. The weight of samples was recorded by weighing on the balance after completion of oven drying.

3.8.2 Yield attributes

The yield attributes were recorded after harvesting of five randomly tagged plants. The attributes are given below:

3.8.2.1 Number of pods plant^{-1}

Number of pods were recorded at the maturity stage before harvesting by picking of pods from the branches of 5 randomly selected tagged plants from each plot and were averaged and expressed as a total number of pods plants^{-1}.

3.8.2.2 Number of grains pod^{-1}

Number of grains pod^{-1} were recorded at the maturity stage before harvesting after picking of pods from the branches of 5 randomly tagged plants from each plot and values were averaged and expressed as a total number of grains pod^{-1}.

3.8.2.3 Test weight (g)

One thousand grains were randomly counted from pods of each plot and were weighed by using an electronic balance and recorded as test weight.

3.8.3 Yield

3.8.3.1 Grain yield (kg ha^{-1} GP)

The grains obtained from the harvested pods were sun-dried, cleaned and weighed separately from each plot for calculating the grain yield in kg ha^{-1} GP (guava plantation).

3.8.3.2 Stover yield (kg ha^{-1} GP)

The plants of each plot were harvested and sundried and then weighted. The stover yield was obtained after subtracting the weight of grains $plot^{-1}$ from the biological yield $plot^{-1}$ and finally expressed in terms of stover yield (kg ha^{-1} GP).

3.8.3.3 Biological yield (kg ha^{-1} GP)

The weight of thoroughly sundried plants harvest pods was recorded and expressed as biological yield in kg ha^{-1} GP.

3.8.3.4 Harvest index (%)

Harvest index was obtained by dividing the economic yield to biological yield (grain + stover) of each plot separately and multiplied by 100. It was calculated for each plot and was presented in percentage. The following formula was used.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

where,

Economic yield = Grain yield

Biological yield = Grain yield + Stover yield

3.9 Characteristic features of the tree species

The variety of guava (Lucknow - 49) grown under an agri-horticulture system which is also known as "Sardar Guava" a semi-dwarf tree 2.3-3.4 m tall, vigorous, branching type with flat crown leaves are about 12.8-13.2 cm in length and 6-6.8 cm width, ovate to oblong in shape. The average weight of each fruit is between 71.4-145.0 g, having acidic flavour and attractive aroma with more seeds.

3.9.1 Growth attributes of guava

The height of the guava was measured from the plant base to the growing tip of the main stem. The height of the plant is measured and expressed in meters. Using meter tape, the canopy area of guava was recorded from the highest canopy diameter in meters. The stem girth of guava was recorded in centimeters from the plant base.

3.9.1.1 Tree height (m)

The height of guava was measured from base of the plant up to growing tip of main stem. The plant height was measured and expressed in meters.

3.9.1.2 Canopy diameter (m)

The canopy area of guava was recorded using meter tape and recorded from highest canopy diameter in meters.

3.9.1.3 Tree girth (m)

Using a meter tape, the stem girth of each fruit tree situated near the plot was recorded at breast height and its average was computed.

3.9.1.4 Crown length (m)

The crown length of the guava tree was recorded from the first branch to the growing tip of the main stem and expressed in meters.

3.9.1.5 Shading area

The shading area of guava was calculated with the help of meter tape and measured as length and width in meters.

Table 3.6: Measurement of guava tree at the time of lentil sowing

	Plant height (m)	Girth (m)	Canopy Diameter (m)	Crown length (m)	Shading area	
					Length (m)	Width (m)
Guava	5.20	0.360	5.57	4.03	3.61	3.06

Table 3.7: Measurement of guava tree at the time of lentil harvesting

	Plant height (m)	Girth (m)	Canopy Diameter (m)	Crown length (m)	Shading area	
					Length (m)	Width (m)
Guava	5.48	0.373	5.60	4.24	3.96	3.22

3.9.1.6 Number of branches tree^{-1}

The branches on each tree were individually counted and recorded.

3.9.2 Yield attributes and yield (kg ha^{-1}) of guava

3.9.2.1 Number of fruits tree^{-1}

Number of fruits tree^{-1} were counted on the basis of visual count and then average number of fruits were calculated.

3.9.2.2 Average fruit weight (g) and fruit yield (kg ha^{-1})

Total fruit weight was recorded by measuring it on balance and then average was calculated.

3.10 Economics

The cost of inputs that were prevailing at the time of their use was considered for working out the economics of various treatment combinations.

Expenditure cost for various operations i.e. ploughing, harvesting, sowing, weeding, plant protection, harvesting & threshing were calculated per hectare as per normal rates prevalent at the Research Farm, BHU, Barkachha, Mirzapur. The cost of fertilizers, plant protection chemicals and seeds etc. were taken as a market price. The cost of different inputs is mentioned in Appendix III.

3.10.1 Gross return (₹ ha^{-1})

It was calculated by multiplying productivity of lentil grain and stover with market price and summing the values.

3.10.2 Net return (₹ ha^{-1})

It was calculated by subtracting cost of cultivation of each plot from gross income.

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

3.10.3 Benefit-cost ratio (B:C)

Benefit Cost Ratio of various treatments was worked with the help of following formula:

$$\textbf{Benefit Cost Ratio} = \frac{\text{Net return } (₹\ \text{ha}^{-1})}{\text{Cost of Cultivation} (₹\ \text{ha}^{-1})}$$

3.11 Statistical Analysis of data

The data collected during the experimental period and after completion of the experiment were analysed statistically as per the standard analysis of variance to draw valid conclusion **(Gomez and Gomez, 1984)**. On the basis of null hypothesis treatment differences were tested by 'F' test was significance. At 5 % level of probability critical differences were worked out.

The standard error of mean (SEm±) and critical difference (CD) were further computed, when variance ratio (F–test) reported significant at 5% level of significance. DMRT (Duncan's Multiple Range Test) was used wherever the 'F' test was found to be significant using STAR 2.0.1 package (Statistical Tool for Agricultural Research, by IRRI). Formula mentioned below is used to compute the standard error of mean and critical difference.

$$\text{SEm}\pm = \sqrt{\frac{V_e}{r}}$$

$$(\text{C.D.})_{5\,\%} = \text{SEm}\pm \times\sqrt{2}\times \text{t value}$$

Analysis of variance

The experiment was laid in split-plot design under guava based agri-horticulture system keeping 4 doses of nitrogen + phosphorus + sulphur in the main plot and 3 concentrations of urea as foliar spray in sub-plots with three replications.

Representation of Experimental Data

The result of various treatments on experimental crop was shown in tabulated form and illustrated by graphs at specific places. Details of significant mean table values are described in details.

Table 3.8: Schematic representation of ANOVA of a split plot experiment

S.V	D.F	S.S	MSS	F. cal	F. tab	NS/SIG
Replication (r)	2					
Main	3					
Error (a)	6					
Sub	2					
M×S	6					
Error (b)	16					
Total	35					

Where,

r = number of replication;

a = doses of nitrogen + phosphorus + sulphur;

b = concentrations of urea as foliar spray

Chapter IV

EXPERIMENTAL FINDINGS

The present investigation entitled **"Effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** was conducted at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Varanasi (Uttar Pradesh) during *Rabi* (winter) season of 2021-2022. The factors comprised four treatments doses of N, P and S together in main plot and in subplot three concentrations of urea as foliar spray. The result showing the effect of nitrogen, phosphorus, sulphur doses and concentrations of urea as foliar spray on growth attributes, yield attributes, yield and economics of lentil is presented in this chapter under the following headings and subheadings.

4.1 Growth attributes

4.1.1 Plant height (cm)

Data pertaining to the plant height of lentil as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) at 30, 60, 90 DAS, and at harvest stage of the crop are presented in Table 4.1.

Data in table 4.1 revealed that an increment in the plant height at all the stages of observation (30, 60, 90 DAS, and at harvest) due to increasing doses of nitrogen + phosphorus + sulphur (DNPS) was found to be significant. Application of various concentrations of urea as foliar spray (CUFS) resulted in significant effect on plant height at 60, 90 DAS, and at harvest stage, however, at 30 DAS its impact was found to be non-significant.

Application of $N_{23.5+}P_{60+}S_{40}$ recorded significantly maximum plant height compared to $N_{0+}P_{0+}S_{0}$ and it was at par with $N_{20+}P_{50+}S_{30}$. Application of $N_{20+}P_{50+}S_{30}$ recorded a higher plant height over $N_{20+}P_{40+}S_{20}$ and $N_{0+}P_{0+}S_{0}$. Additionally, $N_{20+}P_{40+}S_{20}$ recorded significantly higher plant height than $N_{0+}P_{0+}S_{0}$. However, the minimum plant height was found in $N_{0+}P_{0+}S_{0}$.

Foliar application of urea @ 2% spray at pre-flowering stage followed by 2% urea spray at pod initiation stage resulted in a significant increase in the plant height of lentil over water spray and it was found to be at par with urea @ 2% spray at pre-flowering stage at 60, 90 DAS and at harvest stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher plant height in comparison to water spray at pre-flowering stage. However, the minimum plant height recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on plant height was found to be non-significant.

Table 4.1: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on plant height (cm) of lentil under guava based agri-horti system

Treatment	**30 DAS**	**60 DAS**	**90 DAS**	**At harvest**
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)				
$N_{0}+P_{0}+S_{0}$	4.21c	15.29b	20.83c	26.98c
$N_{20}+P_{40}+S_{20}$	4.98b	16.57a	24.89b	31.73b
$N_{20}+P_{50}+S_{30}$	5.53a	17.15a	25.57ab	33.50a
$N_{23.5}+P_{60}+S_{40}$	5.83a	17.45a	26.35a	34.38a
SEM (±)	0.13	0.29	0.36	0.48
C.D(P = 0.05)	0.46	0.99	1.24	1.65
Concentrations of Urea as Foliar Spray (CUFS)				
Water spray at PF*	5.03	16.22b	23.74b	30.25b
Urea 2% at PF*	5.14	16.71a	24.52a	32.09a
Urea 2% at PF* *fb* 2% at PI**	5.25	16.92a	24.97a	32.60a
SEM (±)	0.06	0.16	0.18	0.30
C.D. (P = 0.05)	NS	0.47	0.53	0.90
NPS×U	NS	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

4.1.2 Number of branches plant^{-1}

Data concerning number of branches plant^{-1} of lentil as influenced by DNPS and CUFS at 30, 60, 90 DAS, and at harvest stage of the crop are illustrated in Table 4.2.

Number of branches plant^{-1} due to doses of nitrogen + phosphorus + sulphur (DNPS) was found to be significant at all the stages of observation (30, 60, 90 DAS, and at harvest stage) and the concentrations of urea as foliar spray (CUFS) was found to be significant at 60, 90 DAS, and at harvest stage, however, at 30 DAS its impact was found to be non-significant.

Application of $N_{23.5+}P_{60+}S_{40}$ recorded significantly higher number of branches plant^{-1} over $N_{20+}P_{50+}S_{30}$, $N_{20+}P_{40+}S_{20}$ and $N_{0+}P_{0+}S_{0}$ at all the stages of observations. Application of $N_{20+}P_{50+}S_{30}$ recorded significantly higher number of branches plant^{-1} over $N_{0+}P_{0+}S_{0}$ and it was found to be statistically similar with $N_{20+}P_{40+}S_{20}$. Similarly, $N_{20+}P_{40+}S_{20}$ recorded significantly higher number of branches plant^{-1} compared to $N_{0+}P_{0+}S_{0}$. However, the minimum number of branches plant^{-1} was observed in $N_{0+}P_{0+}S_{0}$.

Foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage was found maximum number of branches plant^{-1} at 60, 90, and at harvest stage which was at par with 2% urea spray at pre-flowering stage and significantly higher over water spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher number of branches plant^{-1} compared to water spray at pre-flowering stage. However, the minimum number of branches plant^{-1} recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on number of branches plant^{-1} of lentil was found to be non-significant.

Table 4.2: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on number of branches plant^{-1} of lentil under guava based agri-horti system

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)				
$N_{0}+P_{0}+S_{0}$	3.54c	6.55c	9.78c	11.29c
$N_{20}+P_{40}+S_{20}$	4.01b	7.16b	10.76b	12.45b
$N_{20}+P_{50}+S_{30}$	4.36b	7.66ab	11.38ab	13.05ab
$N_{23.5}+P_{60}+S_{40}$	4.80a	8.11a	12.07a	13.59a
SEM (±)	0.11	0.17	0.25	0.29
C.D(P = 0.05)	0.40	0.60	0.87	1.01
Concentrations of Urea as Foliar Spray (CUFS)				
Water spray at PF*	4.08	7.14b	10.69b	12.24b
Urea 2% at PF*	4.21	7.43a	11.01a	12.62a
Urea 2% at PF* *fb* 2% at PI**	4.25	7.54a	11.29a	12.93a
SEM (±)	0.05	0.09	0.10	0.12
C.D. (P = 0.05)	NS	0.27	0.30	0.36
NPS×U	NS	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS

4.1.3 Number of green leaves plant^{-1}

Data pertaining to the number of green leaves plant^{-1} of lentil as influenced by DNPS and CUFS at 30, 60, and DAS of the crop are presented in Table 4.3.

The higher number of green leaves plant^{-1} was reported at 60 DAS. After a certain period of time, the leaves begin to turn yellow. As a result, the number of green leaves plant^{-1} was reduced at 90 DAS.

Variations in number of green leaves plant^{-1} of lentil due to doses of nitrogen + phosphorus + sulphur was found to be significant at all the stages of observation (30, 60, and 90 DAS) and the concentrations of urea as foliar spray was found to be significant at 60 and 90 DAS, however, at 30 DAS it was found to be non-significant.

Application of $N_{23.5+}P_{60+}$ S_{40} recorded significantly higher number of green leaves plant^{-1} in comparison to $N_{20+}P_{50+}S_{30,}$ $N_{20+}P_{40+}S_{20,}$ and $N_{0+}P_{0+}S_{0}$. Application of $N_{20+}P_{50+}S_{30}$ recorded higher number of green leaves plant^{-1} over $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher number of green leaves plant^{-1} was observed in $N_{20+}P_{40+}S_{20}$ than $N_{0+}P_{0+}S_{0}$. However, the lowest number of green leaves plant^{-1} was recorded in $N_{0+}P_{0+}S_{0}$.

At 60 and 90 DAS, foliar application of 2% urea at pre-flowering stage followed by 2% urea at pod initiation stage recorded maximum number of green leaves plant^{-1} over water spray at pre-flowering stage but was at par with 2% urea spray at pre-flowering stage. Likewise, spray with 2% urea at pre-flowering stage recorded significantly higher number of green leaves plant^{-1} in comparison to water spray at pre-flowering stage. However, the minimum number of green leaves plant^{-1} was observed due to application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on number of green leaves plant^{-1} was found to be non-significant.

Table 4.3: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on the number of green leaves plant^{-1} on lentil under guava based agri-horti systems

Treatment	**30 DAS**	**60 DAS**	**90 DAS**
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)			
N_{0}+P_{0}+S_{0}	27.59c	612.43c	465.23d
N_{20}+P_{40}+S_{20}	28.87b	662.71b	487.87c
N_{20}+P_{50}+S_{30}	29.53ab	678.13b	510.63b
$N_{23.5}$+P_{60}+ S_{40}	30.18a	729.04a	536.07a
SEM (±)	0.32	13.39	6.27
C.D(P = 0.05)	1.12	46.35	21.70
Concentrations of Urea as Foliar Spray (CUFS)			
Water spray at PF*	28.73	654.23b	488.78b
Urea 2% at PF*	29.05	672.18a	503.44a
Urea 2% at PF* *fb* 2% at PI**	29.37	685.32a	507.64a
SEM (±)	0.17	5.59	2.70
C.D. (P = 0.05)	NS	16.76	8.08
NPS×U	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

4.1.4 Number of root nodules plant^{-1}

Data pertaining to the number of root nodules plant^{-1} of lentil as influenced by DNPS and CUFS at 30 and 60 DAS of the crop are presented in Table 4.4.

The number of root nodules plant^{-1} were increased with the advancement of crop growth from 30 to 60 DAS.

Effect of doses of nitrogen + phosphorus + sulphur (DNPS) on root nodules plant^{-1} of lentil was found to be significant at 30 and 60 DAS and concentrations of urea as foliar spray (CUFS) was found to be significant at 60 DAS, however, at 30 DAS its impact was found to be non-significant.

The number of root nodules plant^{-1} was found to be highest with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$ and significantly higher over $N_{0+}P_{0+}S_{0}$ at 30 and 60 DAS. Application of $N_{20+}P_{50+}S_{30}$ recorded higher number of root nodules plant^{-1} over $N_{20+}P_{40+}S_{20}$ and $N_{0+}P_{0+}S_{0}$. Additionally, $N_{20+}P_{40+}S_{20}$ recorded significantly higher number of root nodules plant^{-1} compared to $N_{0+}P_{0+}S_{0}$. However, the minimum number of root nodules plant^{-1} recorded in $N_{0+}P_{0+}S_{0}$.

At 60 DAS, the highest number of root nodules plant^{-1} due to foliar application of urea was recorded with the treatment of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage over water spray at pre-flowering stage and it was found to be statistically comparable with 2% urea spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher number of root nodules plant^{-1} compared to water spray at pre-flowering stage. However, the lowest number of root nodules plant^{-1} was recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on number of root nodules plant^{-1} was found to be non-significant.

Table 4.4: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on a number of root nodules plant^{-1} of lentil under guava based agri-horti system

Treatment	30 DAS	60DAS
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)		
$N_{0}+P_{0}+S_{0}$	7.37b	14.57c
$N_{20}+P_{40}+S_{20}$	8.84a	17.22b
$N_{20}+P_{50}+S_{30}$	9.10a	17.96ab
$N_{23.5}+P_{60}+S_{40}$	9.22a	18.84a
SEM (±)	0.15	0.32
C.D(P = 0.05)	0.52	1.09
Concentrations of Urea as Foliar Spray (CUFS)		
Water spray at PF*	8.53	16.59b
Urea 2% at PF*	8.66	17.25a
Urea 2% at PF* *fb* 2% at PI**	8.71	17.61a
SEM (±)	0.05	0.18
C.D. (P = 0.05)	NS	0.53
NPS×U	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

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

Data pertaining to dry matter accumulation plant^{-1} of lentil as influenced by DNPS and CUFS at 30, 60, 90 DAS, and at harvest stage of the crop are presented in Table 4.5.

Variations in dry matter accumulation plant^{-1} of lentil due to doses of nitrogen + phosphorus + sulphur was found to be significant at all the stages of observation (30, 60, 90 DAS, and at harvest) and the concentrations of urea as foliar spray was found to be significant at 60, 90 DAS, and at harvest stage, however, at 30 DAS its impact was found to be non-significant.

The maximum dry matter accumulation plant^{-1} was found with the application of $N_{23.5+}P_{60+}S_{40}$ which was significantly higher compared to $N_{20+}P_{50+}S_{30}$, $N_{20+}P_{40+}S_{20}$ and $N_{0+}P_{0+}S_{0}$ at 30, 60, 90 DAS, and harvest stage. Application of $N_{20+}P_{50+}S_{30}$ recorded higher dry matter accumulation plant^{-1} compared to $N_{20+}P_{40+}S_{20}$ and $N_{0+}P_{0+}S_{0}$. Similarly, $N_{20+}P_{40+}S_{20}$ recorded significantly higher dry matter accumulation plant^{-1} compared to $N_{0+}P_{0+}S_{0}$. However, the minimum dry matter accumulation plant^{-1} recorded in $N_{0+}P_{0+}S_{0}$.

At 60, 90 DAS, and at harvest stage, foliar application of urea @ 2% spray at pre-flowering stage followed by 2% urea spray at pod initiation stage recorded significantly higher dry matter accumulation plant^{-1} over water spray and it was at par with urea @ 2% spray at pre-flowering stage at 60, 90 DAS and at harvest stage. Likewise, spray with 2% urea at pre-flowering stage recorded significantly higher dry matter accumulation plant^{-1} over water spray at pre-flowering stage. However, the minimum dry matter accumulation plant^{-1} recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on dry matter accumulation was found to be non-significant at all the stages of observations.

Table 4.5: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on dry matter accumulation plant^{-1} of lentil under the guava based agri-horti system

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)				
$N_{0}+P_{0}+S_{0}$	0.42c	7.19c	16.94c	22.36d
$N_{20}+P_{40}+S_{20}$	0.51b	7.62bc	17.97b	26.84c
$N_{20}+P_{50}+S_{30}$	0.59ab	7.94b	18.78ab	28.49b
$N_{23.5}+P_{60}+S_{40}$	0.63a	8.49a	19.59a	30.48a
SEM (±)	0.03	0.15	0.28	0.32
C.D(P = 0.05)	0.09	0.53	0.98	1.10
Concentrations of Urea as Foliar Spray (CUFS)				
Water spray at PF*	0.52	7.63b	17.92b	26.23b
Urea 2% at PF*	0.53	7.85a	18.35a	27.21a
Urea 2% at PF* *fb* 2% at PI**	0.56	7.95a	18.70a	27.69a
SEM (±)	0.01	0.07	0.13	0.24
C.D. (P = 0.05)	NS	0.20	0.39	0.71
NPS×U	NS	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

4.2 Yield attributes

4.2.1 Number of pods plant^{-1}

Data pertaining to number of pods plant^{-1} of lentil as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.6.

Data in table 4.6 revealed that an increment in the number of pods plant^{-1} due to doses of nitrogen + phosphorus + sulphur and concentrations of urea as foliar spray was found to be significant.

Application of $N_{23.5+}P_{60+}S_{40}$ recorded significantly higher no. of pods plant^{-1} over $N_{0+}P_{0+}S_0$ but it was at par with $N_{20+}P_{50+}S_{30}$. Treatment ($N_{20+}P_{50+}S_{30}$) had statistically similar number of pods plant^{-1} compared to $N_{20+}P_{40+}S_{20}$. Additionally, $N_{20+}P_{40+}S_{20}$ recorded significantly higher number of pods plant^{-1} compared to $N_{0+}P_{0+}S_0$. However, the minimum number of pods plant^{-1} recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of urea, the maximum number of pods plant^{-1} recorded with the application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was significantly superior over water spray and it was at par with 2% urea spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher number of pods plant^{-1} in comparison to water spray at pre-flowering stage. However, the minimum number of pods plant^{-1} recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on number of pods plant^{-1} was found to be non-significant.

4.2.2 Number of grains pods^{-1}

Data concerning number of grains pod^{-1} of lentil as influenced due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) of the crop are presented in Table 4.6.

The maximum number of grains pod^{-1} was found with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$ and significantly higher over $N_{0+}P_{0+}S_0$. Application of $N_{20+}P_{50+}S_{30}$ had statistically equivalent number of grains pod^{-1} compared to $N_{20+}P_{40+}S_{20}$. Similarly, $N_{20+}P_{40+}S_{20}$ recorded significantly higher number of grains pod^{-1} in comparison to $N_{0+}P_{0+}S_0$. However, the minimum number of grains pod^{-1} recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of urea, the maximum number of grains pod^{-1} recorded with the application of 2% urea spray at pre-flowering stage followed by 2%

urea spray at pod initiation stage which was significantly higher over water spray but it was at par with 2% urea spray at pre-flowering stage. Likewise, spray with 2% urea at pre-flowering stage recorded significantly higher number of grains pod^{-1} over water spray at pre-flowering stage. However, the minimum number of grains pod^{-1} recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on number of grains pod^{-1} was found to be non-significant.

4.2.3 Test weight

The data presented in Table 4.6 revealed significant variations in test weight of lentil due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS).

Data in table 4.6 revealed that an increment in the test weight due to increasing doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) was found to be significant.

The maximum test weight was found with the application of $N_{23.5+}P_{60+}S_{40}$ which was significantly higher over $N_{0+}P_{0+}S_0$ and it was at par with $N_{20+}P_{50+}S_{30}$. Application of $N_{20+}P_{50+}S_{30}$ recorded statistically similar test weight compared to treatment $N_{20+}P_{40+}S_{20}$. Likewise, $N_{20+}P_{40+}S_{20}$ recorded significantly higher test weight compared to $N_{0+}P_{0+}S_0$. However, the minimum test weight recorded in $N_{0+}P_{0+}S_0$.

In case foliar application of urea, the maximum test weight was found with the treatment of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage and significantly higher over water spray at pre-flowering stage. Further, spray with 2% urea recorded significantly higher test weight compared to water spray at pre-flowering stage. However, the minimum test weight recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on test weight was found to be non-significant.

Table 4.6: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on yield attributes on lentil under guava based agri-horti systems

Treatment	**No. of pods plant^{-1}**	**No. of grains pod^{-1}**	**Test weight(g)**
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)			
$N_{0}+P_{0}+S_{0}$	72.10c	1.34c	20.18c
$N_{20}+P_{40}+S_{20}$	82.04b	1.77b	23.22b
$N_{20}+P_{50}+S_{30}$	86.22ab	1.90ab	23.87ab
$N_{23.5}+P_{60}+S_{40}$	90.58a	2.01a	24.77a
SEM (±)	2.43	0.06	0.41
C.D(P = 0.05)	8.42	0.21	1.41
Concentrations of Urea as Foliar Spray (CUFS)			
Water spray at PF*	79.05b	1.58b	21.85b
Urea 2% at PF*	83.32a	1.79a	23.31a
Urea 2% at PF* *fb* 2% at PI**	85.84a	1.88a	23.87a
SEM (±)	1.03	0.04	0.20
C.D. (P = 0.05)	3.08	0.12	0.59
NPS×U	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

4.3 Yield

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

Data pertaining to grain yield of lentil as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.7.

Variations in grain yield due to doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray was found to be significant.

Application of $N_{23.5+}P_{60+}$ S_{40} recorded significantly higher grain yield in comparison to $N_{0+}P_{0+}S_0$ but it was at par with $N_{20+}P_{50+}S_{30}$. Treatment with $N_{20+}P_{50+}S_{30}$ had statistically equivalent grain yield compared to $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher grain yield was recorded in $N_{20+}P_{40+}S_{20}$ over $N_{0+}P_{0+}S_0$. However, the minimum grain yield recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of urea, the maximum grain yield recorded with the application of 2% urea spray at pre-flowering stage followed 2% urea spray at pod initiation stage which was significantly superior over water spray but was at par with 2% urea spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher grain yield over water spray at pre-flowering stage. However, the minimum grain yield recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on grain yield was found to be non-significant.

4.3.2 Stover yield (kg ha^{-1} GP)

Data concerning stover yield of lentil as influenced due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) of the crop are illustrated in Table 4.7.

Data in table 4.7 revealed that an increment in stover yield due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) was found to be significant.

Application of $N_{23.5+}P_{60+}$ S_{40} recorded the maximum stover yield which was at par with $N_{20+}P_{50+}S_{30}$ and significantly higher over $N_{0+}P_{0+}S_0$. Application of $N_{20+}P_{50+}S_{30}$ has statistically similar stover yield compared to $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher stover yield was found in $N_{20+}P_{40+}S_{20}$ compared to $N_{0+}P_{0+}S_0$, whereas, the minimum stover yield recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage resulted in maximum stover yield over water spray at pre-flowering stage and it was at par with 2% urea spray at pre-flowering stage. Treatment with 2% urea spray produced significantly higher stover yield of lentil in comparison to water spray at pre-flowering stage. However, the minimum stover yield of lentil recorded in water spray at pre-flowering stage.

Interaction effect on stover yield of lentil due to doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) was found to be non-significant.

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

Data pertaining to biological yield of lentil as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.7.

Biological yield due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) was found to be significant.

The maximum biological yield was found with the application of $N_{23.5+}P_{60+}S_{40}$ which was significantly superior over $N_{0+}P_{0+}S_0$ and it was at par with $N_{20+}P_{50+}S_{30}$. Application of $N_{20+}P_{50+}S_{30}$ recorded statistically similar biological yield compared to $N_{20+}P_{40+}S_{20}$. Likewise, significantly higher grain yield recorded in $N_{20+}P_{40+}S_{20}$ over $N_{0+}P_{0+}S_{0.}$ However, the minimum biological yield recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of urea, the maximum biological yield recorded with the application of 2% urea spray at pre-flowering stage followed 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage and significantly superior over water spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher biological yield over water spray at pre-flowering stage. However, the minimum biological yield recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on biological yield of lentil was found to be non-significant.

4.3.4 Harvest Index (%)

Data concerning harvest index of lentil as influenced due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) of the crop are presented in Table 4.7.

Variations in harvest index due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) was found to be significant.

Application of $N_{23.5+}P_{60+}$ S_{40} recorded the maximum harvest index which was significantly higher over $N_{0+}P_{0+}S_0$ and it was found to be statistically similar with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. Application of $N_{20+}P_{50+}S_{30}$ recorded statistically comparable harvest index compared to $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher harvest index recorded in $N_{20+}P_{40+}S_{20}$ compared to $N_{0+}P_{0+}S_0$. However, the minimum harvest index was found in $N_{0+}P_{0+}S_0$.

Foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage recorded the maximum harvest index over water spray at pre-flowering stage and it was at par with 2% urea spray at pre-flowering stage. Treatment with 2% urea spray led to a significantly higher harvest index compared to water spray at pre-flowering stage. However, the minimum harvest index was found with the application of water spray at pre-flowering stage.

Interaction effect on harvest index of lentil due to doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) was found to be non-significant.

Table 4.7: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on yield of lentil (0.6857 ha) under guava based agri-horti systems

Treatment	**Grain yield (kg ha^{-1} GP)**	**Stover yield (kg ha^{-1} GP)**	**Biological yield (kg ha^{-1} GP)**	**Harvest index (%)**
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)				
$N_{0}+P_{0}+S_{0}$	422.09c	771.03c	1542.06c	27.37b
$N_{20}+P_{40}+S_{20}$	643.03b	1014.07b	2028.15b	31.71a
$N_{20}+P_{50}+S_{30}$	708.18ab	1108.78ab	2217.55ab	31.90a
$N_{23.5}+P_{60}+S_{40}$	768.36a	1157.69a	2315.38a	33.17a
SEM (±)	19.70	29.78	59.55	0.45
C.D(P = 0.05)	68.17	103.04	206.08	1.55
Concentration of Urea as Foliar Spray (CUFS)				
Water spray at PF*	594.84b	979.12b	1958.24b	30.03b
Urea 2% at PF*	647.70a	1018.44a	2036.87a	31.47a
Urea 2% at PF* *fb* 2% at PI**	663.70a	1041.12a	2082.24a	31.61a
SEM (±)	11.78	12.78	25.56	0.38
C.D. (P = 0.05)	35.33	38.31	76.63	1.15
NPS×U	NS	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction; GP = Guava plantation

4.4 Economics

4.4.1 Gross return (₹ ha^{-1})

Data pertaining to gross return of the agri-horti system as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.8.

Gross return due to doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) was found to be significant.

The maximum gross return was found with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$ and significantly higher over $N_{0+}P_{0+}S_{0}$. Application of $N_{20+}P_{50+}S_{30}$ had statistically equivalent gross return compared to with $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher gross return recorded in $N_{20+}P_{40+}S_{20}$ over $N_{0+}P_{0+}S_{0}$. However, the minimum gross return recorded in $N_{0+}P_{0+}S_{0}$.

In case of foliar application of urea, the maximum gross return was recorded with the application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was significantly higher over water spray but it was at par with 2% urea spray at pre-flowering stage. Likewise, spray with 2% urea at pre-flowering stage recorded significantly higher gross return over water spray at pre-flowering stage. However, the minimum gross return recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on gross return of the agri-horti system was found to be non-significant.

4.4.2 Net return (₹ ha^{-1})

Data pertaining to net return of the agri-horti system as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.8.

Variations in net return of agri-horti system due to doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray was found to be significant.

Application of $N_{23.5+}P_{60+}S_{40}$ recorded the maximum net return which was at par with $N_{20+}P_{50+}S_{30}$ and significantly higher over $N_{0+}P_{0+}S_{0}$. Application of $N_{20+}P_{50+}S_{30}$ had statistically equivalent net return compared to $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher net return was recorded in $N_{20+}P_{40+}S_{20}$ over $N_{0+}P_{0+}S_{0}$, whereas, the minimum net return was found in $N_{0+}P_{0+}S_{0}$.

Foliar application of 2% urea at pre-flowering stage followed by 2% urea at pod initiation stage earned a maximum net return over water spray at pre-flowering stage and it was at par with 2% urea spray at pre-flowering stage. Treatment with 2% urea spray resulted in significantly higher net return in comparison to water spray at pre-flowering stage. However, the minimum net return recorded in water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on net return of the agri-horti system was found to be non-significant.

4.4.3 Benefit-cost Ratio

Data pertaining to benefit-cost ratio of the agri-horti system as influenced by doses of nitrogen + phosphorus + sulphur (DNPS) and concentrations of urea as foliar spray (CUFS) are presented in Table 4.8.

Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on benefit-cost ratio of the agri-horti system was found to be significant.

Application of $N_{23.5+}P_{60+}$ S_{40} recorded significantly higher benefit-cost ratio over $N_{0+}P_{0+}S_0$ but it was at par with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. Application of $N_{20+}P_{50+}S_{30}$ had statistically comparable benefit-cost ratio compared to $N_{20+}P_{40+}S_{20}$. Similarly, significantly higher benefit-cost ratio recorded in $N_{20+}P_{40+}S_{20}$ compared to $N_{0+}P_{0+}S_0$. However, the minimum benefit-cost ratio recorded in $N_{0+}P_{0+}S_0$.

In case of foliar application of urea, the maximum benefit-cost ratio was found with the application of 2% urea spray at pre-flowering stage followed 2% urea spray at pod initiation stage which was significantly superior over water spray but was at par with 2% urea spray at pre-flowering stage. Similarly, spray with 2% urea at pre-flowering stage recorded significantly higher benefit-cost ratio compared to water spray at pre-flowering stage. However, the minimum benefit-cost ratio recorded with the application of water spray at pre-flowering stage.

Interaction effect of doses of nitrogen + phosphorus + sulphur (DNPS), and concentrations of urea as foliar spray (CUFS) on benefit-cost ratio of the agri-horti system was found to be non-significant.

Table 4.8: Combined economics of treatments under guava + lentil based agri-horti system

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})				Net return (₹ ha^{-1})	Benefit-cost ratio
		Grain	Stover	Fruit	Total		
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)							
$N_{0+}P_{0+}S_0$	32785.64	23214.75c	3855.16c	88896.25	115966.16c	83180.52c	2.54b
$N_{20+}P_{40+}S_{20}$	35258.06	35366.88b	5070.37b	88896.25	129333.50b	94075.45b	2.67a
$N_{20+}P_{50+}S_{30}$	36049.14	38949.66ab	5543.88ab	88896.25	133389.80ab	97340.66ab	2.70a
$N_{23.5+}P_{60+}S_{40}$	36875.18	42260.07a	5788.45a	88896.25	136944.77a	100069.59a	2.71a
SEM (±)	-	1083.46	148.88	-	1221.96	1221.96	0.03
C.D. (P = 0.05)	-	3749.39	515.21	-	4228.69	4228.69	0.12
Concentrations of Urea as Foliar Spray (CUFS)							
Water spray at PF*	35194.30	32716.46b	4895.61b	88896.25	126508.32b	91314.02b	2.59b
Urea 2% at PF*	35242.19	35623.54a	5092.18a	88896.25	129611.97a	94369.79a	2.67a
Urea 2% at PF* *fb* 2% at PI**	35289.53	36503.53a	5205.61a	88896.25	130605.38a	95315.85a	2.70a
SEM (±)	-	648.06	63.89	-	700.80	700.80	0.02
C.D. (P = 0.05)	-	1942.98	191.56	-	2101.10	2101.10	0.06
NPS×U	NS	NS	NS	NS	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction

DISCUSSION

The present investigation entitled **"Effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system"** was conducted at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Varanasi (Uttar Pradesh) during *Rabi* (winter) season of 2021-2022. In this chapter, the results of the experimental trials are detailed and discussed. Prior to discussing the results of the experimentation, it is important to mention about the soil of the experimental site, it was sandy clay loam in texture, with good drainage. The nutrient status of the soil was low in nitrogen, sulphur, and organic matter but medium in phosphorus and potassium content. The findings of previous researchers are also quoted while discussing the present experimentation.

5.1 Effect of weather on crops

Experimental findings are influenced by the weather conditions. The weather components, including temperature (minimum and maximum), sunlight hours, relative humidity, and rainfall, that were observed throughout the crop's duration are shown in Table 3.1. The effect on growth and development was also recorded due to variations in the weather components. For better growth, development, and achieving potential yield, lentil requires optimum temperature (18 to 30°C), rainfall (650 to 850 mm), sunshine hours (11.2 to 11.4), and relative humidity (50% to 90%). However, poor growth and minimum yield are recorded in lentil if the fluctuations or variations become too wide from the optimum weather condition. Lentil is a *Rabi* season crop and weather during that period was found to be compatible with germination, growth and development.

Lentil grows and blooms well in a cold climate. It requires cool conditions or low temperature for vegetative growth and high temperature and low humidity for maturity. The optimum temperature requirements for the growth of lentils ranges between 18 and 30°C. According to Dhuppar *et al*. (2012), the lentil has a low tolerance for high temperatures, which is especially harmful during blooming and pod set stage.

The experimentally collected meteorological data shown in Table 3.1 revealed that the average temperature (11 to 28°C) during growing season was observed within the cardinal range for crop growth.

Water requirements for the growth and development of lentil range from 650 to 850 mm, and during the entire experiment, rainfall was 31.2 mm which is low. Therefore, satisfactory growth and development was achieved by the crop through irrigation at a critical stage to the crop.

Relative humidity for the growth and development of lentil ranged from 50% to 90%, and during the entire experiment, average relative humidity ranged from 37% to 90% which is good for lentil growth and development.

5.2 Effect of nitrogen + phosphorus + sulphur

5.2.1 Growth attributes

The experimental findings presented in (Tables 4.1 to 4.5) indicated that doses of nitrogen + phosphorus + sulphur revealed a significant impact on the growth attributes of lentil. Various growth attributes such as plant height, number of branches plant^{-1}, number of green leaves plant^{-1}, root nodules plant^{-1}, and dry matter accumulation plant^{-1} were influenced by the doses of nitrogen + phosphorus + sulphur at 30, 60, 90, and at harvest stage.

Generally, the plant height increased rapidly during 30 to 60 DAS and thereafter declined from 90 DAS to the harvest stage. Among all the treatments, $N_{23.5+}P_{60+}S_{40}$ recorded maximum plant height at various intervals of crop growth (Table 4.1) and it was statistically at par with $N_{20+}P_{50+}S_{30}$. However, the minimum plant height was observed in $N_{0+}P_{0+}S_{0}$. Plant height of lentil increased with increasing doses of nitrogen + phosphorus + sulphur, which might be due to the increased availability of nitrogen, phosphorus and sulphur under acidic soil of the field experiment. Nitrogen availability helps to enhance the plant's biological processes including growth, absorption, and translocation, phosphorus helps in metabolic activities, cell enlargement and the development of new tissues and sulphur helps in cell division, cell expansion and cell elongation of plant ultimately contributing to an increase in plant height. Similar results were also observed by Singh *et al*. (2018).

Generally, the number of branches increased with the advancement in its age and the number of green leaves plant^{-1} increased rapidly during 30 to 60 DAS and thereafter declined upto 90 DAS and beyond. The maximum no. of branches plant^{-1} (Table 4.2) and number of green leaves plant^{-1} (Table 4.3) in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$. However, the minimum number of branches plant^{-1} and number of green leaves plant^{-1} was recorded in control ($N_{0+}P_{0+}S_{0}$). The number of branches plant^{-1} and number of green leaves plant^{-1} was increased with higher doses of N, P and S, which might be due to the increased availability of nitrogen, phosphorus and sulphur and more photosynthesis by leaves. Similar results were also recorded by Yogesh *et al*. (2009) and Singh *et al*. (2018).

Generally, the number of root nodules plant^{-1} increases with increasing crop growth. The highest number of root nodules plant^{-1} in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ (Table 4.4) which was at par with $N_{20+}P_{50+}S_{30}$ at 60 DAS. However, the lowest number of root nodules plant^{-1} was observed in $N_{0+}P_{0+}S_{0}$. The increased number of root nodules plant^{-1} might be due to the increased availability of nitrogen, phosphorus and sulphur under acidic soil of the field experiment. Nitrogen availability helps in accelerating the nodules metabolism, phosphorus application helps to maintain healthy root nodules growth and rhizobial activity. Sulphur availability in nodulation was positively linked to more symbiotic nitrogen fixation by accelerating nodule metabolism ultimately contributes to an increase in the formation of root nodules. Similar results were also recorded by Singh *et al*. (2018).

Generally, dry matter accumulation plant^{-1} increased with the advancement in its age. The maximum dry matter accumulation plant^{-1} in lentil was recorded with the application $N_{23.5+}P_{60+}S_{40}$ (Table 4.5) and the minimum dry matter accumulation plant^{-1} was observed in $N_{0+}P_{0+}S_{0}$. Dry matter accumulation increased with increasing doses of nitrogen + phosphorus + sulphur. This might be due to an increase in plant height (Table 4.1), number of branches (Table 4.2) and number of green leaves (Table 4.3) resulting in a better light interception by crop to accumulate more photosynthates and thus produced more dry matter. Similar results were also reported by Yogesh *et al*. (2009) and Singh *et al*. (2018).

5.2.2 Yield and yield attributes

The experimental findings presented in (Tables 4.6 and 4.7) indicated that doses of nitrogen + phosphorus + sulphur revealed a significant impact on the yield attributes and yield of lentil. Various yield attributes and yield such as number of pods plant^{-1}, number of grains pod^{-1}, test weight, grain yield, stover yield, biological yield and harvest index were influenced by the doses of nitrogen + phosphorus + sulphur.

The maximum number of pods plant^{-1}, number of grains pod^{-1} and test weight in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ (Table 4.6) and it was at par with $N_{20+}P_{50+}S_{30}$. However, the minimum number of pods plant^{-1}, no. of grains pod^{-1} and test weight was observed in $N_{0+}P_{0+}S_{0}$. The number of pods plant^{-1}, number of grains pod^{-1} and test weight was significantly higher with increasing doses of nitrogen + phosphorus + sulphur, which might be due to more dry matter accumulation in respective treatments (Table 4.5). Similar results were also reported by Yogesh *et al*. (2009) and Singh *et al*. (2018).

The maximum grain yield in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ and it was found statistically at par with $N_{20+}P_{50+}S_{30}$. (Table 4.7) However, the minimum grain yield was observed in $N_{0+}P_{0+}S_{0}$. The increase in grain yield with increasing doses of nitrogen + phosphorus + sulphur, might be due to increases in yield attributes *viz*. number of pods plant^{-1}, number of grains pod^{-1} and test weight. (Table 4.6) Similar results were also observed by Yogesh *et al*. (2009) and Singh *et al*. (2018).

The maximum stover yield in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30}$. (Table 4.7) However, the minimum stover yield recorded in $N_{0+}P_{0+}S_{0}$. Stover yield increase might be due to the availability of more nitrogen, phosphorus and sulphur in the acidic soil of the field experiment which helps to increase plant height (Table 4.1), number of branches (Table 4.2) and dry matter accumulation (Table 4.5) ultimately improving the stover yield. Similar results were also recorded by Singh *et al*. (2018).

The maximum biological yield in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ and it was statistically similar with $N_{20+}P_{50+}S_{30}$. (Table 4.7) However, the minimum biological yield was observed in $N_{0+}P_{0+}S_{0}$. Grain yield and stover yield were increased with higher doses of nitrogen, phosphorus and sulphur, the biological yield also increased.

The highest harvest index in lentil was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ but was at par with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. (Table 4.7) However, the lowest harvest index was observed in $N_{0+}P_{0+}S_{0}$. Grain yield were increased with higher doses of nitrogen, phosphorus and sulphur, the harvest index also increased.

5.2.3 Economics

Economics (Table 4.8) of agri-horti system was significantly influenced by doses of nitrogen + phosphorus + sulphur. The grain and stover yield were maximum in $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$. Thus, the gross return, net return, and benefit-cost ratio was also maximum in $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$. However, the highest benefit-cost ratio recorded in $N_{23.5+}P_{60+}S_{40}$ but was at par with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20.}$ The combined economics of lentil and guava are better as compared to mono-cropping system of lentil. This might be due to additional profits of guava being included in economics of agri-horti system. Similar results were also reported by Singh *et al*. (2018).

5.3 Effect of concentrations of urea as foliar spray

5.3.1 Growth attributes

The experimental findings presented in (Tables 4.1 to 4.5) indicated that concentrations of urea as foliar spray revealed a significant impact on the growth attributes of lentil. Various growth attributes such as plant height, number of branches plant^{-1}, number of green leaves plant^{-1}, root nodules plant^{-1}, and dry matter accumulation plant^{-1} were influenced by the concentrations of urea as foliar spray at 30, 60, 90 DAS, and harvest stage.

Generally, the plant height, number of branches plant^{-1} and number of green leaves plant^{-1} increased with the advancement in its age. Foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage recorded maximum plant height (Table 4.1), number of branches plant^{-1} (Table 4.2) and number of green leaves plant^{-1} (Table 4.3) at the various interval of crop growth and it was statistically similar with 2% urea spray at pre-flowering stage**.** However, the minimum plant height, number of branches plant^{-1} and number of green leaves plant^{-1} recorded in water spray at pre-flowering stage. Foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage recorded the maximum plant height, number of branches plant^{-1} and number of green leaves plant^{-1}, it might be due to better availability of nitrogen as foliar spray during their active nitrogen-consumption phase, which led to higher cell division and expansion, chlorophyll formation (increased photosynthetic rate) and vegetative growth resulting in increased plant height. Similar results were also reported by Aggarwal (2015), Das and Jana (2016), Pal *et al*. (2020), and Singh *et al*. (2022)

Generally, the number of root nodules plant^{-1} increases from 30 DAS to 60 DAS. The highest number of root nodules plant^{-1} in lentil recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage (Table 4.4) and the lowest number of root nodules plant^{-1} was observed in water spray at pre-flowering stage. The foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage increases the availability of nitrogen in split form, resulting in more nitrogen supply to nodule formation. Similar results were also reported by Aggarwal *et al*. (2015) and Singh *et al*. (2022).

Generally, dry matter accumulation plant^{-1} increased with the advancement in its age. The maximum dry matter accumulation plant^{-1} in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and which was statistically similar to 2% urea spray at pre-flowering stage. (Table 4.5) However, the minimum dry matter accumulation plant^{-1} was observed in water spray at pre-flowering stage. Dry matter accumulation in the plant at all the growth stages *viz.*, 30, 60, 90 DAS and at harvest stage was maximum due to foliar application of 2% urea spray at the pre-flowering stage followed by 2% urea spray at pod initiation stage which might be due to increase in plant height (Table 4.1), number of branches plant^{-1} (Table 4.2) and number of green leaves plant^{-1} (Table 4.3). Similar results were also observed by Das and Jana (2016) and Singh *et al*. (2022)

5.3.2 Yield and yield attributes

The experimental findings presented in (Tables 4.6 and 4.7) indicated that concentrations of urea as foliar spray revealed a significant impact on the yield attributes and yield of lentil. Various yield attributes and yield such as number of pods plant^{-1}, number of grains pod^{-1}, test weight, grain yield, stover yield, biological yield and harvest index respectively were influenced by concentrations of urea as foliar spray.

The maximum number of pods plant^{-1}, number of grains pod^{-1} and test weight in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was statistically similar to 2% urea spray at pre-flowering stage. (Table 4.6) However, the minimum number of pods plant^{-1}, number of grains pod^{-1} and test weight was observed in water spray at pre-flowering stage. The number of pods plant^{-1}, number of grains pod^{-1} and test weight was significantly increased with the increasing concentrations of urea as foliar spray, which might be due to more dry matter accumulation Similar results were also observed by Dixit and Elamathi (2007), Aggarwal *et al*. (2015), and Pal *et al*. (2020).

The maximum grain yield in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was statistically similar with 2% urea spray at pre-flowering stage (Table 4.7) and the minimum grain yield was observed in water spray at pre-flowering stage. The grain yield was significantly increased with the increasing concentrations of urea as foliar spray which might be due to increases in yield attributes *viz*. number of pods plant^{-1}, number of grains pod^{-1} and test weight. Similar results were also observed by Ali and Kumar (2006), Aggarwal *et al*. (2015), Pal *et al*. (2020), and Singh *et al*. (2022).

The maximum stover yield in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was at par with 2% urea spray at pre-flowering stage. (Table 4.7) However, the minimum stover yield was observed in water spray at pre-flowering stage. The stover yield was significantly increased with the increasing concentrations of urea as foliar spray. This might be due to an adequate supply of nitrogen in split form at pre-flowering and pod initiation stage which favour better photosynthesis and translocation which helps to increase plant height, number of branches plant^{-1} and dry matter accumulation plant^{-1} ultimately contributing to an increase in stover yield. Similar results were also recorded by Pal *et al*. (2020).

The maximum biological yield (Table 4.7) in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was statistically comparable with 2% urea spray at pre-flowering stage, whereas the minimum biological yield was observed in water spray at pre-flowering stage. Grain yield and stover yield were increased with the foliar application of 2% urea spray at the pre-flowering followed by 2% urea spray at pod initiation stages, the biological yield also increased. Similar results were also reported by Ali and Kumar (2006), Aggarwal *et al.* (2015), and Singh *et al*. (2022).

The highest harvest index in lentil was recorded with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was found to be at par with 2% urea spray at pre-flowering stage. (Table 4.7) However, the lowest harvest index was observed in water spray at pre-flowering stage. Grain yield were increased with the foliar application of 2% urea spray at the pre-flowering followed by 2% urea spray at pod initiation stages, the harvest index also increased. Similar results were also recorded by Pal *et al*. (2020).

5.3.3 Economics

Economics (Table 4.8) of agri-horti system was significantly influenced by concentrations of urea as foliar spray. The grain and stover yield were maximum with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage. Hence, the gross return, net return, and benefit-cost ratio were also maximum with the foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was also at par with 2% urea spray at pre-flowering stage. The combined economics of lentil and guava are better as compared to a mono-cropping system of lentil. This might be due to additional profits of guava being included in economics of agri-horti system. Similar results were also observed by Pal *et al*. (2020), and Singh *et al*. (2022).

Chapter VI

SUMMARY AND CONCLUSION

This chapter aimed to provide an overview and draw a valid summary based on significant findings from the data presented in the previous chapter as well as a valid conclusion based on significant findings of the current or present investigation, which was designed to study **"Effect of nitrogen, phosphorus and sulphur doses and concentrations of urea as foliar spray on growth and yield of lentil (*Lens culinaris* Medik.) under guava (*Psidium guajava* L.) based agri-horti system".** The investigation was conducted at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Varanasi (Uttar Pradesh) during *Rabi* (winter) season of 2021-2022 with the following objectives:

1. To study the effect of nitrogen, phosphorus and sulphur doses, and concentrations of urea as foliar spray on growth and yield of lentil under guava based agri-horti system.

2. To work out the economics of the treatments.

The soil of experimental site was sandy clay loam with a pH of 5.44 in the year 2021. It was fairly fertile having low organic carbon content (0.34%), low available nitrogen (169.20 kg ha^{-1}), and medium in available phosphorus (17.70 kg ha^{-1}) and potassium (181.20 kg ha^{-1}). The experiment was carried out in split-plot design under guava (spacing 7 m×7 m) based agri-horti system with various doses of $N_{0+}P_{0+}S_{0,}$ $N_{20+}P_{40+}S_{20,}$ $N_{20+}P_{50+}S_{30,}$ $N_{23.5+}P_{60+}S_{40}$ and concentrations of urea as foliar spray (Water spray at PF, 2% urea at PF, 2% urea at PF *fb* by 2% urea at PI). Nitrogen, phosphorus and potassium are applied as basal application and the concentrations of urea as foliar spray are applied at pre-flowering stage and pod initiation stage. Urea is a source of nitrogenous fertilizer for basal and also as foliar spray. For "HUL-57" variety of lentil, the optimum seed requirement is 30 kg ha^{-1} and sown with the use of *Kudal* directly at a row to row and plant to plant distance of 30 cm×5 cm respectively.

Crop response to treatments was measured in terms of various observations pertaining to the growth attributes, *viz*. plant height (cm), number of branches $plant^{-1}$, number of green leaves plant^{-1}, number of root nodules plant^{-1}, and dry matter accumulation plant^{-1} (g) was noted at the various stages of crop growth (30, 60, 90 DAS, and harvest stage) in the experimental crop (lentil) under guava based agri-horti system. Yield attributes and yield, *viz.* number of pods plant^{-1}, number of grains pod^{-1}, test weight, grain yield (kg), stover yield (kg), biological yield (kg), and harvest index (%). Economics components, *viz*. total cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}), net return (₹ ha^{-1}), and benefit-cost ratio were also calculated. The key findings and conclusions emerging from the investigations are summarized as under:

1. Doses of nitrogen + phosphorus + sulphur had significant impact on plant height at all the stages of observations (30, 60, 90 DAS, and harvest stage) and the maximum plant height was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$. Plant height was significantly influenced by concentrations of urea as foliar spray at 60, 90 DAS and at harvest stage and the maximum plant height was recorded under foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was at par with 2% urea spray at pre-flowering stage.

2. Number of branches plant^{-1} was significantly influenced by doses of nitrogen + phosphorus + sulphur at 30, 60, 90 DAS, and harvest stage and the higher number of branches plant^{-1} was achieved with the application of $N_{23.5+}P_{60+}S_{40}$. Concentrations of urea as foliar spray also significantly influenced the number of branches plant^{-1} at all the stages of crop growth and the maximum number of branches plant^{-1} was recorded under those plots which were treated with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage at 60, 90 DAS and at harvest stage.

3. Number of green leaves plant^{-1} was significantly influenced by doses of nitrogen + phosphorus + sulphur at 30, 60, 90 DAS, and harvest stage and the higher number of green leaves plant^{-1} was achieved with the application of $N_{23.5+}P_{60+}S_{40}$ at 60 DAS. Concentrations of urea as foliar spray also significantly influenced the number of green leaves plant^{-1} at all the stages of crop growth and the maximum number of green leaves plant^{-1} was recorded under those plots

which were treated with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was statistically similar with 2% urea spray at pre-flowering stage at 60, 90 DAS and at harvest stage.

4. The effect of various doses of nitrogen + phosphorus + sulphur on number of root nodules plant^{-1} was found to be significant. The maximum number of root nodules plant^{-1} was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30}$. Concentrations of urea as foliar spray also significantly influenced the number of root nodules plant^{-1} at all the stages of crop growth and the maximum number of root nodules plant^{-1} was recorded under those plots which were treated with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was statistically similar with 2% urea spray at pre-flowering stage at 60 DAS.

5. Doses of nitrogen + phosphorus + sulphur had significant effect on dry matter accumulation plant^{-1} at 30, 60, 90 DAS, and harvest stage. The maximum dry matter accumulation plant^{-1} was observed with the application of $N_{23.5+}P_{60+}S_{40.}$ Dry matter accumulation plant^{-1} was significantly influenced by concentrations of urea as foliar spray at all the stages of observation and the maximum dry matter accumulation plant^{-1} was observed with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was at par with 2% urea spray at pre-flowering stage at 60, 90 DAS and at harvest stage.

6. Doses of nitrogen + phosphorus + sulphur had significant effect on number of pods plant^{-1}. The maximum number of pods plant^{-1} was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray also significantly influenced the number of pods plant^{-1} and the maximum number pods plant^{-1} was recorded under those plots which were treated with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage.

7. Doses of nitrogen + phosphorus + sulphur had significant impact on number of grains pod^{-1}. The maximum number of grains pod^{-1} was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray also significantly influenced the number of grains pod^{-1} and the maximum number of grains pod^{-1} was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage.

8. The test weight was significantly influenced by doses of nitrogen + phosphorus + sulphur. The maximum test weight was observed with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray also significantly influenced the test weight and the maximum test weight was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was at par with 2% urea spray at pre-flowering stage.

9. Grain yield was significantly influenced by doses of nitrogen + phosphorus + sulphur. The maximum grain yield was observed with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30}$. Concentrations of urea as foliar spray also significantly influenced the grain yield and the maximum grain yield was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage.

10. Doses of nitrogen + phosphorus + sulphur had a significant impact on stover yield. The maximum stover yield was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray also significantly influenced the stover yield and the maximum stover yield was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage and it was at par with 2% urea spray at pre-flowering stage.

11. Doses of nitrogen + phosphorus + sulphur had significant effect on biological yield. The maximum biological yield was found with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar

spray also significantly influenced the biological yield and the maximum biological yield was recorded under those plots which were treated with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage.

12. Harvest index was significantly influenced by doses of nitrogen + phosphorus + sulphur. The maximum harvest index was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. Concentrations of urea as foliar spray also significantly influenced the harvest index. The maximum harvest index was found with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage.

13. Total cost of cultivation was increased with the increasing doses of nitrogen + phosphorus + sulphur and concentrations of urea as foliar spray. The highest cost of cultivation was reported with the treatment of $N_{23.5+}P_{60+}S_{40.}$ In case of foliar spray, the maximum cost of cultivation was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage.

14. Gross return of the agri-horti system was significantly influenced by doses of nitrogen + phosphorus + sulphur. The maximum gross return was recorded with the application of $N_{23.5+}P_{60+}S_{40}$ which was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray was also significantly influenced the gross return of the agri-horti system. The maximum gross return was found with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage and the minimum gross return recorded with water spray at pre-flowering stage.

15. Doses of nitrogen + phosphorus + sulphur had significant impact on net return of the agri-horti system. The maximum net return was found with the application of $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30.}$ Concentrations of urea as foliar spray also significantly influenced the net return of the agri-

horti system and the maximum net return was recorded with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation which was at par with 2% urea spray at pre-flowering stage and the minimum net return recorded with water spray at pre-flowering stage.

16. Benefit-cost ratio of the agri-horti system was significantly influenced by doses of nitrogen + phosphorus + sulphur. The highest benefit-cost ratio was observed with the application of $N_{23.5+}P_{60+}S_{40}$ and it was statistically similar with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. Concentrations of urea as foliar spray also significantly influenced the benefit-cost ratio of the agri-horti system. The highest benefit-cost ratio was found with foliar application of 2% urea spray at pre-flowering stage followed by 2% urea spray at pod initiation stage which was at par with 2% urea spray at pre-flowering stage and the lowest benefit-cost ratio was found with water spray at pre-flowering stage.

Conclusion

On the basis of experimental findings, the following conclusion is drawn:

$N_{23.5+}P_{60+}S_{40}$ gave significantly higher plant height, root nodules plant^{-1}, number of pods plant^{-1}, number of grains pod^{-1}, test weight, grain, stover, biological yield, gross and net return which was at par with $N_{20+}P_{50+}S_{30}$. Significantly higher number of branches plant^{-1}, number of green leaves plant^{-1} and dry matter accumulation plant^{-1} was achieved with $N_{23.5+}P_{60+}S_{40}$. Significantly higher harvest index and benefit-cost ratio was recorded with $N_{23.5+}P_{60+}S_{40}$ and it was at par with $N_{20+}P_{50+}S_{30}$ and $N_{20+}P_{40+}S_{20}$. Foliar application of 2% urea spray at PF *fb* by 2% urea spray at PI recorded significantly higher growth, yield, yield attributes and economics which was at par with foliar application of 2% urea spray at PF.

In one year field experimentation under guava-lentil agri-horti system, application of $N_{20+}P_{50+}S_{30}$ and foliar application of 2% urea spray at PF was found to be more remunerative in Vindhyan region of RGSC, Barkachha.

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Appendices

Appendix I: Cost of cultivation for lentil (0.6857 ha) in 1 hectare GP (Guava plantation)

S. No.	Operations	Input	Rate (₹)	Cost (₹)
1.	Land preparation			
	a.) One disc ploughing	One Tractor (35 HP) for 1.5 hrs.	700 hr^{-1}	950
	b.) Two-disc ploughing and planking	One Tractor (35 HP) for 2 hrs.	700 hr^{-1}	1400
2.	Layout	5 labours	300 $labour^{-1}$ day^{-1}	1500
3.	Sowing by manual	5 labours	300 $labour^{-1}$ day^{-1}	1500
4.	Thinning and weed management	7 labours	300 $labour^{-1}$ day^{-1}	2100
5.	Irrigation	Water for 2irrigation	500 $irrigation^{-1}$	1000
		2 labour $irrigation^{-1}$	300 $labour^{-1}$ day^{-1}	1200
6.	Harvesting	8 labours	300 $labour^{-1}$ day^{-1}	2400
7.	Threshing and winnowing	8 labours	300 $labour^{-1}$ day^{-1}	2400
8.	Seed rate (kg ha^{-1})	20.57 kg	70₹ kg^{-1}	1440
Cost of cultivation (₹)				**15890**

APPENDIX II: Treatments wise cost of Fertilizer

S. No.	Treatments	Urea (₹)	DAP (₹)	Sulphur 90% WDG (₹)	MOP (₹)	Total
1	Control ($N_0+P_0+S_0$) + water spray at PF	0	0	0	365	365
2	Control ($N_0+P_0+S_0$) + 2% urea at PF	45	0	0	365	410
3	Control ($N_0+P_0+S_0$) + 2% urea at PF *fb* 2% urea at PI	89	0	0	365	454
4	($N_{20}+P_{40}+S_{20}$) + water spray at PF	42	1431	838	365	2676
5	($N_{20}+P_{40}+S_{20}$) + 2% urea at PF	86	1431	838	365	2720
6	($N_{20}+P_{40}+S_{20}$) + 2% urea at PF *fb* 2% urea at PI	131	1431	838	365	2765
7	($N_{20}+P_{50}+S_{30}$) + water spray at PF	4	1789	1257	365	3415
8	($N_{20}+P_{50}+S_{30}$) + 2% urea at PF	49	1789	1257	365	3460
9	($N_{20}+P_{50}+S_{30}$) + 2% urea at PF *fb* 2% urea at PI	93	1789	1257	365	3504
10	($N_{23.5}+P_{60}+S_{40}$) + water spray at PF	0	2146	1676	365	4187
11	($N_{23.5}+P_{60}+S_{40}$) + 2% urea at PF	45	2146	1676	365	4232
12	($N_{23.5}+P_{60}+S_{40}$) + 2% urea at PF *fb* 2% urea at PI	89	2146	1676	365	4276
*Urea- 6.5 (₹ kg^{-1}), DAP- 24 (₹ kg^{-1}), MOP- 16 (₹ kg^{-1}), Sulphur- (₹ kg^{-1})						**32464**

APPENDIX III: Treatments wise total cost of cultivation of lentil

S.No.	Treatments	Common Cost of Cultivation	Treatment Wise Cost of Fertilizer	Working Capital	Interest on Working Capital @ 7% per 6 months	Land Revenue Per annum	Total cost
1	Control (N_0+P_0+S_0) + water spray at PF	15890	365	16255	1137.85	80	17472.85
2	Control (N_0+P_0+S_0) + 2% urea at PF	15890	410	16300	1141	80	17521
3	Control (N_0+P_0+S_0) + 2% urea at PF *fb* 2% urea at PI	15890	454	16344	1144.08	80	17568.08
4	(N_{20}+P_{40}+S_{20}) + water spray at PF	15890	2676	18566	1299.62	80	19945.62
5	(N_{20}+P_{40}+S_{20}) + 2% urea at PF	15890	2720	18610	1302.7	80	19992.7
6	(N_{20}+P_{40}+S_{20}) + 2% urea at PF *fb* 2% urea at PI	15890	2765	18655	1305.85	80	20040.85
7	(N_{20}+P_{50}+S_{30}) + water spray at PF	15890	3415	19305	1351.35	80	20736.35
8	(N_{20}+P_{50}+S_{30}) + 2% urea at PF	15890	3460	19350	1354.5	80	20784.5
9	(N_{20}+P_{50}+S_{30}) + 2% urea at PF *fb* 2% urea at PI	15890	3504	19394	1357.58	80	20831.58
10	($N_{23.5}$+P_{60}+S_{40}) + water spray at PF	15890	4187	20077	1405.39	80	21562.39
11	($N_{23.5}$+P_{60}+S_{40}) + 2% urea at PF	15890	4232	20122	1408.54	80	21610.54
12	($N_{23.5}$+P_{60}+S_{40}) + 2% urea at PF *fb* 2% urea at PI	15890	4276	20166	1411.62	80	21657.62

APPENDIX IV: Common cost of cultivation for one hectare of guava orchard

Particulars	Input	Rate (₹)	Cost (₹)
Weeding and Pruning	10 Labour	300 day^{-1}	3000.0
Farm Yard Manure	35 kg	4	140
Fertilizer (N, P, K @ 400, 300, 400 g $plant^{-1}$)			
Urea (1/2 dose)	434.8 g $plant^{-1}$	6.5 kg^{-1}	576.5
Superphosphate (SSP)	937.5 g $plant^{-1}$	4.5 kg^{-1}	860.6
Muriate of Potash	333.3 g $plant^{-1}$	16 kg^{-1}	1087.9
Plant protection measure	4 Labour	300 day^{-1}	1200
Harvesting	16	300 day^{-1}	4800
Grading & Packaging	12	300 day^{-1}	3600
TOTAL			15265

APPENDIX V: Growth attributes of fruit tree (guava) at the time of sowing and harvesting At the time of lentil sowing

	Plant height (m)	Girth (m)	Canopy Diameter (m)	Crown length (m)	Shading area	
					Length (m)	Width (m)
Guava	5.20	0.360	5.57	4.03	3.61	3.06

At the time of lentil harvesting

	Plant height (m)	Girth (m)	Canopy Diameter (m)	Crown length (m)	Shading area	
					Length (m)	Width (m)
Guava	5.48	0.373	5.60	4.24	3.96	3.22

APPENDIX VI: Yield and Economics of fruit tree (Guava)

Fruit Tree	**Guava (*Psidium guajava* L.)**				
	R1	**R2**	**R3**	**R4**	**Average**
No. of average fruits tree-1	236	242	245	248	243
No. of average fruits ha-1	48163	49388	50000	50612	49540.75
Average weight of fruit (g)	71.4	72.2	72	71.5	71.77
Fruit yield (kg ha-1)	3438.84	3565.81	3600	3618.76	3555.85
Rate of fruit (₹ kg-1)	25	25	25	25	25
Gross income from fruit trees (₹)	85971	89145.25	90000	90469	88896.25

APPENDIX VII: Effect of doses of nitrogen + phosphorus + sulphur, and concentrations of urea as foliar spray on gross return, net return, benefit-cost ratio of lentil (0.6857 ha) under guava based agri-horticulture system

Treatment	**Gross return (₹ ha^{-1} GP)**	**Net return (₹ ha^{-1} GP)**	**Benefit-cost ratio**
Doses of Nitrogen + Phosphorus + Sulphur (DNPS)			
$N_{0}+P_{0}+S_{0}$	27069.91c	9549.27c	0.54b
$N_{20}+P_{40}+S_{20}$	40437.25b	20444.20b	1.02a
$N_{20}+P_{50}+S_{30}$	44493.55ab	23709.41ab	1.14a
$N_{23.5}+P_{60}+S_{40}$	48048.52a	26438.34a	1.22a
SEM (±)	1221.96	1221.96	0.06
C.D. (P = 0.05)	4228.69	4228.69	0.20
Concentrations of Urea as Foliar Spray (CUFS)			
Water spray at PF*	37612.07b	17682.77b	0.87b
Urea 2% at PF*	40715.72a	20738.54a	1.02a
Urea 2% at PF* *fb* 2% at PI**	41709.13a	21684.60a	1.06a
SEM (±)	700.80	700.80	0.03
C.D. (P = 0.05)	2101.10	2101.10	0.10
NPS×U	NS	NS	NS

* PF = Pre-flowering stage; **PI = Pod initiation stage; NPS×U = DNPS and CUFS interaction; GP = Guava plantation