

Studies on the performance of Soybean + maize intercropping under different farming systems

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

**In partial fulfilment of the requirements
for the Degree of**

MASTER OF SCIENCE

In

**AGRICULTURE
(AGRONOMY)**

By

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2023

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LIST OF SYMBOLS

<u>Abbreviation</u>	<u>Stand for</u>
@	At the rate of
ANOVA	Analysis of variance
cm	Centimeter
CD	Critical difference
F value	Fishers value
d.f.	Degree of freedom
DAS	Day After Sowing
<i>et al</i>	And co- worker
m	Meter
Fig.	Figure
g	Gram
ha	Hectare
kg	Kilogram
Max.	Maximum
Min	Minimum
M.S.S	Mean Sum of Square
i.e.,	That is
mt	Million tonnes
%	Percentage
<i>viz.</i>	Namely
°C	Degree Celsius
q	Quintal
SEm ±	Standard Error of mean
SSTr	Treatment sum of square
SSE	Error sum of square
SST	Total sum of square
MSR	Replication mean sum of square
MST	Treatment means sum of square
S.Ed	Standard error of differences between twotreatments
MSE	Mean square error
t (0.05)	Tabulated „t“ Value at error degree of freedomat p=0.05
C.V	Coefficient of variation
BJG	Beejamrit + Jeevamrit + Ghanajeevamrit
NF	Natural farming
NM	Nutrient management

Chapter – I

INTRODUCTION

INTRODUCTION

Soybean (*Glycine max*) is the world's most important oil seed legume. It is a native of North-eastern China belongs to family Fabaceae. It can grow well in tropical and sub-tropical climate and require warm and moist season. It can thrive in temperature range of 26 to 30°C. Soybean is extensively grown in all over India specially in Madhya Pradesh. It contains 30% carbohydrate and 4% fibres. Therefore, it is also known as golden bean, wonder crop and man-made meat (Morya *et al* 2017).

Area under soybean in India have been estimated to be 11.34 million hectares with the production of 11.99 million tonnes in 2021. Madhya Pradesh stood first with 5.51-million-hectare area and production of 5.56 million tons (SOPA 2021). Soybean have great nutritive value and very high protein content (42-43%) and oil (18-20%) with major essential fatty acids and vitamins (A and D). However, production of soybean in 2020 was 126.10 lakh tonnes and in 2021 it become 119.87 lakh tonnes but it still much below the potential of the crop in India. Thus, the poor productivity of crop and great fluctuation in it has been the major cause of concern in India. Thus, it needs advanced system of productions and intercropping is one of them. In intercropping, cereal-legume intercropping is best complementarily observed in term of nitrogen, which is achieved through the optimal use of soil mineral nitrogen (by cereal) and fixed nitrogen (by legume) in their different growth cycles.

Maize (*Zea mays* L) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies and uses. Beside this maize have many types like normal yellow/ white grain, sweet corn, popcorn, waxy corn, high amylase corn, high corn, quality protein maize, etc. Apart from above, maize is an important industrial raw material and provide large opportunity for value addition.

The average production of the year 2020-21 in India was 31.51 million tonnes in an area of 9.9 million hectare, whereas in kharif 2021, maize production was 21.24 million tonnes in an area of 8.15 million hectares.

In intercropping, the plant density of the base crop is maintained at its optimum and the additional population of the intercrop is added for better use of resources. Besides giving higher output and returns, meeting the multiple needs of the family, spreading out of labour peaks and maintenance of soil fertility, the practice provides greater stability and production (Singh and Jha, 1984). Another distinguishing feature of these new intercropping system is that they are in an 'additive series' which is more efficient than the 'replacement-series' recommended earlier (Singh and Reddy, 1986). Efforts have been made to identify climatically efficient economically viable, feasible and socially acceptable intercropping system for different agro-climatic region.

Organic farming, also known as ecological farming or biological farming, is an agricultural system that uses fertilizers of organic origin such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion crop. On the other hand, natural Farming is a chemical-free alias traditional farming method. It is considered as agroecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity. Integrated farming system is a sustainable agricultural system. that integrates livestock, crop production, fish, poultry, tree crops, plantation crops and other systems that benefit each other. It is based on the concept that 'there is no waste' and 'waste'.

Chemical farming, also known as Intensive farming is the process of growing plants and produce using low crop rotation ratio, high use of labour and extensive use of chemical pesticides and fertilizers. Therefore, agricultural formulations are created organically to reduce the accumulation and destiny of heavy metals and other contaminants in food products. These formulas are made to promote better growth and production using components that are readily available locally such as agricultural byproducts like barn, oil cakes, FYM, etc. Typically, beejamrit, jeevamrit and ghanjeevamrit are used in organic farming. Beejamrit used for the treatment

of plant seedlings or any other planting material. It helps produce IAA and GA3 and protects young roots from fungus, soil-borne diseases, and infections acquired by seeds. Cow manure contains naturally occurring good microorganisms. These microorganisms are cultured and administered to the seeds as inoculum in the form of beejamrit. An excellent alternative to chemical fertilisers is jeevamrit, an excellent source of natural carbon, biomass, for plant growth and development.

To alleviate the problem, INM is an option as it utilizes available organic and inorganic nutrients to build ecologically sound and economically viable farming system. Organic manures, particularly FYM and vermicompost, not only supply macronutrients but also meet the requirements of micronutrients, besides improving soil health. The use of organics plays a major role in maintaining soil health due to buildup of soil organic matter, beneficial microbes. Therefore, integrating organic sources of nutrients and minimum use of chemical fertilizers should be done, to produce optimum crop yield without deteriorating the soil health. Therefore, keeping in view all above facts the present investigation entitled, “Studies on the performance of soybean + maize intercropping under different farming systems.” has been proposed to conduct the following objectives:

- To find out the effect of different farming systems on growth and yield of soybean + maize intercropping.
- To find out suitable production system for soybean+ maize intercropping.
- To work out the economics of different farming systems.

Chapter – II

REVIEW LITERATURE

REVIEW LITERATURE

This chapter reviews the literature on the effects of various nutrient management practices on growth parameters, yield attributes, yield, soil health, and economics of soybean + maize intercropping system

2.1 Effect on Growth

Saxena et al. 2001 conducted a field experiment on soybean during kharif seasons for two years (1996 and 1997) to study the effect of inorganic and organic sources of nutrients on crop. They observed that, application of 50 kg N + 1 tonne neem-cake/ha enhanced plant height, number of triplets plant, plant dry matter, leaf area index, and other growth parameters and seed yield considerably. The highest seed yield was obtained with 25 kg N + 5 tonnes FYM/ha, which was at par with 25 kg N + 1 tonne neem-cake.

Gupta et al. 2003 conducted a experiment to study the morphophysiological attributes and soybean productivity of two distinct varieties (JS-335 and NRC-12) under two organic manure levels and four sulphur levels in Random Block Design at the Instructional Farm, Rajasthan Agriculture College, Udaipur in kharif of the year 2000. It was found that plant height, number of primary branches per plant, leaf area index (LAI), and dry matter accumulation increased with increasing rates (two levels of FYM and four levels of sulphur fertiliser) in both cultivars (soybean cultivars JS- 335 and NRC-12) during kharif 2000 in Udaipur, Rajasthan.

Ramana et al. 2008 conducted a field trial to assess the physiological and biochemical changes in soybean as affected by organic, chemical and integrated nutrient management practices. Results revealed that chemical nutrient management practice recorded higher chlorophyll content and leaf area index (LAI) as compared to organic and integrated nutrient management in soybean.

Devi et al. 2013 observed that combination of 75% RDF with vermicompost @ 1 t/ha and PSB significantly increased plant height, number of nodules/plants, dry weight of nodules/plant, pods plant and seed index of soybean as compared to the other treatments. Similarly, application of 75%

RDF as inorganic fertilizer in combination with vermicompost @ 1 t/ha significantly gave higher seed and stover yield.

Sutar et al. 2015 carried out a field experiment during kharif 2015 at organic farming block of Research Institute on Organic Farming, University of Agricultural Sciences, Bengaluru to study the influence of different levels of jeevamrutha and panchagavya on growth, yield attributes and yield of cowpea in red sandy loam soil. It was reported that the application of jeevamrutha @1000L/ha and panchagavya @7.5% significantly influenced plant height, number of branches, number of leaves, leaf area and leaf area index of cowpea.

Muktamar et al., 2017 conducted a field experiment at CAPS Research Station from April to June 2016, the study aimed to determine performance and major nutrient uptake by sweet corn following application of vermicompost supplemented with liquid organic fertilizer (LOF) and to find out combined vermicompost and liquid organic fertilizer for sweet corn production. It was observed that application of vermicompost had a significant increase in plant height, plant leaf area, shoot fresh and dry weight of sweet corn. The result also concluded that shoot dry matter increased with increasing rates of poultry manure application.

Wailare et al., 2017 observed that the growth parameters of maize viz., plant height and leaf area were found to be highest under INM (Integrated Nutrient Management) of poultry manure (PM) or farm yard manure (FYM) and recommended dose of fertilizers (RDF) which are statistically on par but comparatively higher than T_1 (100% RDF).

Baradhan et al., 2018 carried out field experiment during March to June, 2014 in a randomized block design with three replications. All the treatments were found to significantly influence the growth and yield components of maize. It was reported that among the integrated nutrient management practices, 100 per cent RDF + vermicompost @ 5 tonnes ha^{-1} + soil application of Azospirillum @ 2 kg ha^{-1} resulted in the enhanced values of various growth and yield attributes viz., plant height, leaf area index, dry

matter production, cob length, cob diameter, number of grains cob-1 and yield of maize.

Ramesh et al., 2018 observed that among different treatments, foliar spray of 5 % jeevamrutha on 20, 40 and 60 DAS (T5) recorded significantly higher plant height (202.57 cm) and LAI (8.09) of maize (*Zea mays* L.).

Korat et al., 2022 carried out a investigation at the Instructional Farm, Department of Agronomy, Junagadh Agricultural University, Junagadh, Gujarat during rabi season 2019-20. Results revealed that highest plant height (49.04 cm), number of branches/plant (6.44) was recorded with conventionally grown sole chickpea which was found statistically at par to the organic farming (OF) and significantly the lowest growth was recorded under chickpea intercropped with wheat, application of cow based bioenhancers (LCNF).

2.2 Effect on yield attributes and yield

Nanjappa et al., 2001 conducted a field study, to investigate the effect of integrated nutrient management on yield and nutrient balance in maize (*Zea mays* L.). The study comprised 7 treatments, consisting of recommended dose of inorganic fertilizer, combination of 50 and 75% recommended dose with FYM and vermicompost and only FYM and vermicompost. Combined application of 50 or 75% recommended dose of fertilizer with 12 tonnes/ha FYM or 2.7 tonnes/ha vermicompost caused higher productivity of maize compared with the application of either only inorganic fertilizer or organic sources. Integrated nutrient management resulted in better uptake and less loss of nutrients from the soil.

Dikshit and Khatik 2002 conducted a field experiment to study the effective combination of organic and inorganic nutrient sources on the availability, uptake. quality and yield of soybean (JS 335) in a Typic Haplustert soil of Jabalpur. They reported that among all nutrient sources, 50% of the recommended fertiliser dose (NPK) + 10 t FYM/ha produced the highest soybean seed (16.00 q/ha) and stover (30.75 q/ha) yields.

Vyas et al. 2003 conducted a multiyear field experiment on clay loam soil at the experimental farm of R.A.K. College of Agriculture, Sehore, Madhya

Pradesh, India, and found that a combined application of 5 kg Zn and 10 t FYM/ha increased seed yield (1790 kg/ha) by 18.2% over the control (1515 kg/ha).

Tripathi et al. 2005 carried out a field experiment for two years (2004-2005) during kharif season on sandy clay soil of Jhabua, India to study the effect of different nutrient combinations organic, inorganic and bio-fertilizers on yield attributes, seed and stover yield of soybean. It was found that the mean values of different attributes and yield were highest with 50 percent RDF coupled with vermicompost application @ 2 t/ha, followed by 100 percent RDF coupled with seed treatment with rhizobium and PSB as compared to no fertiliser. The best treatment increased seed and stover yield by 60 percent and 39 percent, respectively.

Aziz et al. 2011 conducted an experiment at KVK Srinagar in randomised complete block design with three replications and 18 treatment combinations comprising three levels of recommended inorganic fertilisers (50, 75, and 100% RD), three levels of organic manures (control, FYM 10 t/ha, and Dalweed 10 t/ha), and two levels of biofertilizers (control and dual inoculation with Rhizobium + PSB). The results showed that increasing the recommended inorganic levels increased seed and stover substantially. FYM at 10 t/ha significantly better results than other organic treatments. Dual inoculation with Rhizobium and PSB showed superior effect over no inoculation. Yield-attributing characteristics such as seed weight and nodule count increased significantly with increasing amount of recommended inorganic fertilizers.

Aher et al. 2012 conducted an experiment at IISS Bhopal, Madhya Pradesh, India. The soybean cultivar JS-335 was grown in RBD with recommended fertiliser doses N, P, K (30:26.2:16.6 kg/ha) under three management practises, namely organic, chemical, and integrated (50:50). The organic farming practise plots had considerably higher seed yield, total biomass, and harvest index (HI) of soybean than the chemical farming practise and integrated farming practise plots.

Machhar et al. 2012 carried out field experiment was conducted at Krishi Vigyan Kendra, Anand Agricultural University, Dahod during kharif 2011 and 2012 to study the “Effect of organic manures, fertilizers and bio-fertilizers on growth and yield of soybean (*Glycine max*). It was observed that various growth and yield attributing characters of soybean were significantly higher under the application of FYM @ 10.0 t/ha and the lowest under. no organic manure treatment. The highest seed and stover yield pooled in consecutive three trials were recorded with treatment M3 (10.0 t FYM) over rest of the treatments in soybean.

Jat et al., 2013 observed that number of cobs/plants, length of cob/plant, number of grains/cobs, 1000-grain weight, stover and grain yield were maximum on the application of @120 kg N/ha + bio-fertilizers (*Rhizobium* + *Azospirillum* + PSB) with maize + two rows of mung bean over maize + one row of mung bean and sole maize.

Kalhature et al., 2013 carried out a experiment to study the effect of Integrated nutrient management in maize (*Zea Mays L.*) for increasing production with sustainability. Results showed that maize grain yield was increased by 252.38% over control and 147.62% over application of 100% RDF with combined use of organic and inorganic fertilizers which was 7.4 t/ha with highest gross return (₹95.9x10³ /ha) and net return (₹54.2x10³ /ha).

Kannan et al., 2013 conducted a field study at Vanavarayar Institute of Agriculture, Manakkadavu, during November 2012-January 2013 to study the effect of INM on soil fertility and productivity on maize (*Zea mays*). He showed that INM practice including vermicompost and recommended dose of NPK showed its best results with respect to leaf area and plant height as compared to other treatments. INM practice including vermicompost and recommended dose of NPK showed its best results with respect to yield parameters like number of grains per cob, 100 seed weight and yield (4112 kg ha⁻¹). Weight of the cob was recorded maximum in INM practice including FYM and recommended dose of NPK.

Seth et al. 2016 conducted a field experiment during 2012-13 and 2013-14 on a silty clay-loam soil of Palampur, Himachal Pradesh, to study the

productivity and economics of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] + chickpea (*Cicer arietinum* L.) intercropping under irrigation and nutrient management. It was concluded that the soil treatment with jeevamrit in 1:10 ratio and seed inoculation with *Azospirillum*/ *Rhizobium* + PSB, vermicompost 10 t/ha and three sprays of vermiwash significantly gave highest seed and stover yield of gram as compared to integrated nutrient management.

Wailare et al., 2017 conducted a field experiment during the winter season of 2013 at a main research field of the School of Agriculture Lovely Professional University, Phagwara, Punjab (India) to study the influence of integrated nutrient management on growth and yield parameters of maize (*Zea mays* L.) as well as soil physico-chemical properties. Results revealed that highest number of grains per cob (423), total cobs weight per plant (1171.3 g), Test weight (35.9 g) and stover yield (13.84 t/ha) were significantly recorded under INM compared to T₁ (100% RDF).

Baradhan et al., 2018 carried out field experiment during March to June, 2014 and was conducted in randomized block design with three replications. All the treatments were found to significantly influence the growth and yield components of maize. It was reported that among the integrated nutrient management practices evaluated, 100 per cent RDF + vermicompost @ 5 tonnes ha⁻¹ + soil application of *azospirillum* @ 2 kg ha⁻¹ resulted in the enhanced values of various growth and yield attributes viz., plant height, leaf area index, dry matter production, cob length, cob diameter, number of grains cob⁻¹ and yield of maize.

As per NITI Aayog 2018 conducted a study to evaluate the yield of major crops in the three selected states for three categories of farm crops-farmers using Jeevamritha, Beejamritha, etc. along with available Farm Yard Manure (NF with FYM), NF without FYM and conventional/chemical farming (non-NF). It was found that natural farming (NF) with FYM has marginally higher yield (53.79 q/ha) in paddy based cropping system. Similarly, for black gram, non-NF harvested 5.4 q/ha while it is 6.4 q/ha for NF with FYM and 3.7 q/ha for NF without FYM. However, similar trend was observed in sugarcane cropping system.

Ramesh et al., 2018 conducted a field experiment during July to October 2016 under deep clay soil at the Experimental farm, Faculty of Agriculture, Annamalai University to study the effect of organic foliar nutrition on growth and yield of maize (*Zea mays* L.). He concluded that among the various treatments, foliar spray of 5 % jeevamrutha on 20, 40 and 60 DAS (T5) registered significantly higher cob length (22.38 cm) and cob girth (14.07 cm) and hundred grains weight (28.93 g).

Singh et al., 2018 conducted a field experiment at Tulsi Krishi Vigyan Kendra, Chitrakoot, Uttar Pradesh during 2012–13 to 2015–16 to study the effect of organic and inorganic inputs on productivity of soybean (*Glycine max* L. Merrill) based cropping systems. It was reported that Inorganic management recorded significantly highest seed yield (2829 kg/ha), SEY (2129 kg/ha) followed by integrated (2698 kg/ha, 2090 kg/ha) and organic practice (2097 kg/ha, 1630 kg/ha) during kharif season.

Vema et al., 2018 showed that integrated nutrient management treatments in maize and wheat cropping system laid in seven treatments and three replications in completely randomized block design. Treatments receiving organics for substituting 25% N either through fortified vermicompost or vermicompost gave higher numerical values of yield and yield attributes among the organics and inorganics combinations.

Awasthi N. et al., 2020 conducted a study to evaluate the influence of organic and zero budget natural farming on growth and yield of Soybean (*Glycine max*. L) under mountainous conditions of Himachal Pradesh. It was observed that highest plant height was recorded at 30, 60, 90 and harvest with the application of T6- Vermicompost - 10 t/ha + vermiwash- 3 Spray and lowest in T7 - Ghanjivamrit - 125 kg/ha. Highest seed yield (825 kg/ ha) and yield attributes of Soybean crop were recorded in the treatment T6 Vermicompost @ 10t/ha + 3 sprays of vermiwash during the experiment.

Ravisankar et al., 2020 compared the concoctions (Ghanjeevamrit, Beejamrit and Jeevamrit) of natural farming compared with AI-NPOF developed organic farming package and integrated crop management practice under basmati-wheat cropping system. Yield reduction ranging from

31.8 to 37.7% in basmati rice (2018) and 55.1 to 58.6% in wheat (2017-18 & 2018-19) due to application of only concoctions of natural farming compared to the integrated crop management.

Walia et al., 2021 conducted a field experiment at Ludhiana, Punjab, during 2015–16 and 2016–17, to study the effect of organic, integrated and chemical sources of nutrition on growth and productivity of maize (*Zea mays* L.). It was reported that integrated management of nutrient application resulted in 12.52% more grain yield than 100% NPK. Treatment with organic management package (T2) comprising bio-fertilizer containing N and P carriers exhibited 7.09% more grain yield than 100% NPK.

Choudhary et al., 2022 observed that under zero budget natural farming (ZBNF) ghanjeevamrit + jeevamrit + mulching was found to produce significantly highest highest seed yield {wheat (1767.3 kg ha⁻¹), gram (734.1 kg ha⁻¹) under wheat- gram intercropping system.

Jain et al., 2022 conducted a experiment during 2019 and 2020 at College of Agriculture, Sumerpur (Rajasthan) to study the effect of organic weed management and organic nutrient management treatments practices on maize (*Zea mays* L.) in split plot design with 3 replications. It was observed that 75% RDN through vermicompost in two split + seed treatment with beejamurt+spray of jeevamurt twice recorded maximum plant height of 157.2 and 184.9 cm while plant dry matter of 44.1 and 206.18 g plant⁻¹ in maize as compared to lowest recorded in 100% RDN through FYM at 50 DAS and at harvest, respectively.

Das et al., 2023 observed that different natural farming practices in soybean + maize intercropping gave the maximum sole yield under AI-NPOF packages with 26.1 q/ha followed by complete natural farming with 21.4 q/ha whereas other treatments remained non-significant.

Ghasal et al., 2023 conducted a field experimentation to evaluate the comparative performance of integrated crop management, organic management and natural farming on crop growth, productivity, profitability and soil health under basmati rice-wheat system in Upper Indo-Gangetic Plains. It

was observed that test weight of 1000-grains of basmati rice and wheat were observed highest under ICM followed by organic management.

Khan et al., 2023 conducted a comparative study on green gram cultivation in natural farming vs recommended practices was carried out at Krishi Vigyan Kendra, Abusar Jhunjhunu in Kharif-2022 to assess future possibilities of Natural farming practices in the district. He reported that under green gram cultivation in natural farming vs recommended practices, lower yield in natural farming plots (4.54 q/ha) were observed than recommended practices (5.82 q/ha).

Raveena et al., 2023 revealed that significantly higher grain yield (27.38 q/ha) of maize was statistically recorded under application of jeevamrit spray at 14 days interval on maize + lobia intercropping which was found to be statistically at par with maize + soybean with jeevamrit spray at 14 days interval (25.99 q/ha).

2.3 Effect on soil properties

Jat et al., 2004 conducted an experiment in Indore (M.P.) and observed that soil test crop response N27P69K40 + 5 t FYM/ha + S20 was most effective in increasing soybean productivity, increased uptake of N, P, K, sulphur, and zinc plant nutrients, and residual balance of these nutrients in post-harvest soil except available nitrogen.

Choudhary et al 2022 conducted a field experiment at Zero Budget Natural Farm (ZBNF), Holta, Department of Organic Agriculture and Natural Farming, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur H.P to evaluate the comparative efficacy of different components of natural farming in wheat + gram cropping system under Subhash Palekar natural farming (SPNF). The experiment consisted of 8 treatments in randomized block design with three replications. Different treatments influenced organic carbon content of the soil significantly after harvest of the crops. Application of ghanjeevamrit+ jeevamrit + mulching recorded significantly higher organic carbon (0.94 and 1.08%, respectively) and was remained at par with ghanjeevamrit + mulching, jeevamrit + mulching.

Hangarge et al. 2002 conducted a field experiment at Parbhani and found that applying vermicompost at 5 t per ha + organic booster at 1lit per m² increased the availability of N, P, K, and organic carbon in soil. They also concluded that the recommended doses of N, P, K, and organic sources could not perform appreciably on when applied alone. The combined effect of organic + inorganic sources revealed to be superior to either organic alone or an organic + inorganic fertiliser combination.

Hati et al., 2006 conducted a field experiment to study the effects of combined use of inorganic fertilizer (NPK) and organic manure (farmyard manure) on soil physical properties, water-use efficiency, root growth and yield of soybean [*Glycine max* (L.) Merr.] in a soybean–mustard cropping system. Application of 10 Mg farmyard manure and recommended NPK (NPK + FYM) to soybean for three consecutive years improved the organic carbon content of the surface (0–15 cm) soil from an initial value of 4.4 g kg⁻¹ to 6.2 g kg⁻¹ and also increased seed yield and water-use efficiency by 103% and 76%, respectively, over the control.

Mahmood et al., 2017 conducted a field study to investigate the effects of organic and inorganic manures on maize and their residual impacts on soil physico-chemical characteristics. It was concluded that soil pH and soil bulk density decreased due to application of organic fertilizer and showed a negative correlation with grain yield. Further, a significant and positive correlation was observed among maize grain yield and available N, P and K contents, respectively in the soil. Conclusively, integration of inorganic fertilizers with organic manures can be used with optimum rates to improve crop productivity on sustainable basis.

2.4 Effect on economics

Shwetha et al., 2008 observed the effect of organic nutrient management in a soybean-wheat cropping system in Dharwad and concluded that the net returns in soybean were significantly higher with combined application of organic and fermented liquid manures over no fermented liquid manures and recorded significantly higher B:C ratio (2.9) with the application

of compost + vermicompost + green leaf manure followed by compost green leaf manure beejamrit + jeevamrit + panchagavya (2.6)

Yadav et al. 2009 conducted a study was done from 2003–2008 at Kumarganj, Faizabad to assess the impact of organic manures on performance of (*Oryza sativa* L.)–wheat (*Triticum aestivum* (L.) Fiori & Paol.) system. Among the various organic farming treatments, the incorporation of crop residues in both crops + green manuring + phosphorus solubilizing microbes + poultry manure at a rate of 5 tonnes per hectare + neem cake at a rate of 0.2 tonnes per hectare yielded the highest values of growth, yield and its components, as well as net returns. This treatment also yielded the highest B:C ratio (1.60). All organic farming practises improved soil health, evidenced by increased carbon and decreased soil ph.

Bachhav and colleagues 2010 conducted a field experiment on loamy sand soil at Agriculture Research Station Farm. Anand Agricultural University, Anand, during Kharif 2010. Four different organic manures, No (No organic), CC (Castor cake @ 0.5 t/ha), VC (vermicompost @ 1 t/ha), and FYM (FYM @ 5 t/ha), and four different levels inorganic fertiliser, F0 (No RDF), F1 (50% RDF), F2 (75% RDF), and F3 (100% RDF), were tried in Randomised Block Design with Factorial concept and replicated four times. The FYM sprayed at 5 t/ha produced the highest seed yield (1,908 kg/ha), haulm yield (3,588 kg/ha), gross realisation, and net realisation with BCR compared to the other treatments. Application of 100% RDF (60 kg N: 30 P₂O₅: 0 kg K₂O) resulted in considerably greater seed yield (1,868 kg/ha), haulm yield (3,537 kg/ha), gross realisation, gross realisation, and BCR. Significantly, the combination of FYM + 100% RDF resulted in the greatest net realisation of Rs. 30,815/ha with BCR 3.21 (i.e. FYM @ 5 t/ha+ 100% RDF).

Chandel et al., 2010 studied the resource matrix and economics of organically grown crops and practises at the CSK HPKV organic research farm in Palampur. The cost of producing organic inputs such as vermicompost, NADEP compost, vermi-wash, matkakhad, BD compost, CPP compost, compost tea, agnihotra ash, and truibecum ash was estimated to be Rs. 1.91/kg, Rs. 1.51/kg, Rs. 4.43/L, Rs. 1.85/L, Rs. 2.18/kg, Rs. 10/kg, Rs. The economic study of organically produced maize and wheat revealed

that the highest feasible net returns on the farm with the combination of the above organic inputs were assessed to be Rs. 74,286 and Rs. 63,104 per hectare in the case of maize and wheat, respectively.

Ramesh et al. 2010 carried out a field experiment was conducted during rainy (kharif) and winter (rabi) seasons of 2004-08 to study the effect of different combination of organic manures involving cow dung manure, poultry manure and vermicompost vis-à-vis recommended doses of fertilizers and control on the yield potential, soil fertility and economics of soybean [*Glycine max* (L.) Merr.], chickpea (*Cicer arietinum* L.) and blond psyllium or isabgol (*Plantago ovata* Forsk) in deep Vertisols of central India. It was found that integrated application of cow dung manure, vermicompost, and poultry manure in a soybean-chickpea cropping system produced the highest gross monetary returns (Rs. 43.927), net returns (Rs. 23.890), and benefit cost ratio (2.19).

Das et al., 2023 found that the system BC ratio was highest under AI-NPOF Packages (1.82) followed by complete natural farming (1.20) in maize intercropping system.

Raveena et al., 2023 conducted a field experiment during kharif 2020 at the Zero Budget Natural Farm (ZBNF), Department of Organic Agriculture & Natural Farming, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, to evaluate the influence of natural and organic farming techniques on the productivity and economics of maize based intercropping systems. It was observed that highest gross returns (205252 ₹/ha), net returns (156132 ₹/ha), benefit cost ratio (3.18) and gross returns per rupee invested (4.18) were noted under maize + soybean and jeevamrit spray at 14 days interval.

Chapter - III

MATERIAL AND METHODS

MATERIAL AND METHODS

A field experiment entitled “**Studies on the performance of soybean + maize intercropping under different farming systems**” was conducted during *kharif* 2022. Various materials and methods employed to perform the investigations in the field are given herewith in detail in this chapter under appropriate headings. The climatic variables having significant impact on crop growth and yield were also recorded.

3.1 Experimental site

The field trial was conducted at Krishi Nagar Farm, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India, during the *kharif* season of 2022. Jabalpur district in Madhya Pradesh, India, is situated between 23°18' N latitude and 79°98' E longitude, at an average altitude of around 411.78 meters (1387.73 ft) above sea level, covering an area of 5198 km². On the research farm, enough physical facilities for conducting the field experiments, such as irrigation, seeds, fertilizers, agricultural equipment and machinery, labours and so on, were available to conduct their research work smoothly.

3.2 Climate

Jabalpur falls under the "Kymore Plateau and Satpura Hills" agro-climatic zone, classified as agro-ecological subregion No. 10.1, characterized by a sub-humid (dry) eco-region encompassing Malwa plateau, Vindhyan Scarp Land, and Narmada Valley. The climate is divided into three distinct seasons: *Kharif* (rainy) season spans from Middle June to September, Rabi (winter) season lasts from October to March, and Zaid (summer) season occurs from April to mid-June. Temperatures fluctuate between 5°C in December and January to as high as 46°C in May and June. The region experiences an average annual rainfall of 1350 mm, with the monsoon typically beginning in the third week of June and extending until the end of September, occasionally lasting until the first week of October. The months of December to February are susceptible to rabi rains. Throughout the seasons, relative humidity levels vary, with 20 to 35% during Zaid, 50 to 60% during rabi, and reaching maximum values of 80 to 95% during the *kharif* season.

3.3 Weather condition

The meteorological data was collected at the College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, and displayed graphically in figure 3.1. The weather data collected during the current investigation for the crop growing season shows consistent patterns with typical climatic values. The maximum weekly temperature ranged from 29.0°C to 42.8°C, while the minimum weekly temperature ranged from 12.6°C to 29.1°C. In the morning, the maximum relative humidity varied from 64.0% to 93%, and in the evening, it ranged from 39% to 79%. Throughout the crop growing season, the crop received a total of 115.6 hours of sunlight, with sunshine hours ranging from 0.2 to 8.2 hours per day. The total seasonal rainfall recorded was 1443.7 mm, which occurred over 57 wet days.

Table 3.1: Weekly meteorological parameters during *Kharif* season 2022-23

Months	MW	Temperature (°C)		Sun Shine (hours)	Rainfall (mm)	Relative humidity		Rainy days
		Max.	Min.			Morning	Evening	
June	23	42.8	29.1	9.2	0	38	17	0
	24	38.3	27.7	5.5	20.8	64	44	1
	25	34.4	25.6	5.1	172.2	84	57	4
	26	34.4	25.6	3.5	68.4	85	60	2
July	27	31.3	25.0	2.8	164.2	90	77	6
	28	33.2	24.7	7.5	57.6	90	67	3
	29	30.5	24.6	2.9	53.8	92	78	4
	30	30.5	24.4	1.9	101.0	93	78	5
	31	31.8	25.2	4.1	16.0	88	67	2
Aug.	32	31.6	25.0	4.4	53.8	88	72	4
	33	29.4	24.0	3.5	135.7	89	75	4
	34	29.0	23.1	2.7	208.1	92	74	3
	35	31.3	24.1	3.9	97.5	90	68	3
Sept.	36	31.9	24.3	4.7	47.0	87	72	2
	37	30.5	24.2	4.3	118.0	91	79	4
	38	29.8	23.6	3.2	39.3	92	79	7
	39	30.4	22.3	5.9	0.0	91	65	0
Oct.	40	31.5	22.6	6.2	27.4	88	67	1
	41	30.9	22.4	7.0	62.3	90	64	2
	42	29.4	16.0	9.2	0.0	84	49	0
	43	30.0	13.5	9.2	0.0	83	40	0
Nov.	44	29.8	12.6	8.9	0.0	85	39	0
	45	30.8	13.4	7.8	0.0	85	41	0

Source: Meteorology observatory JNKVV Jabalpur (Madhya Pradesh)

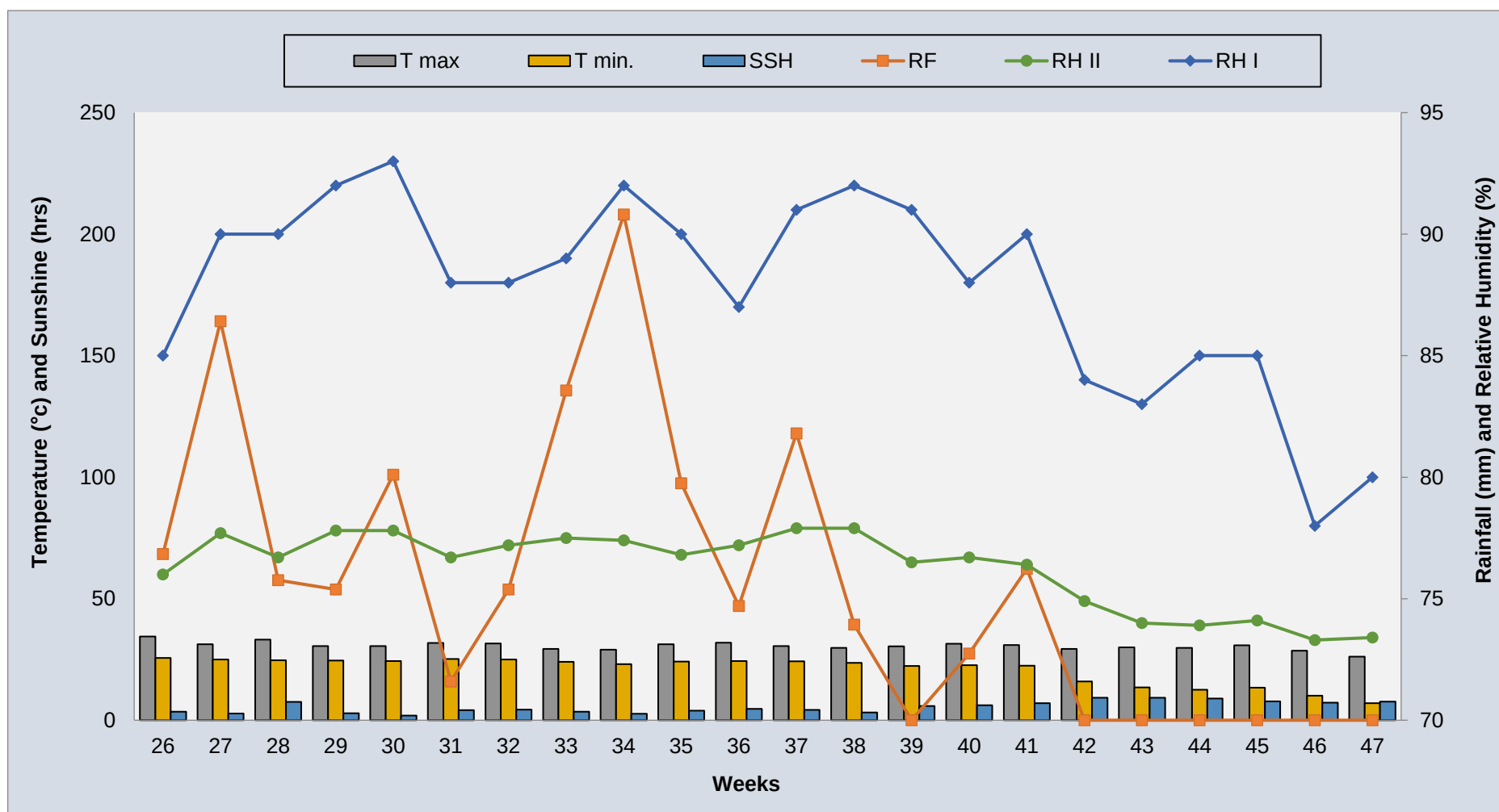


Fig. 3.1: Weekly meteorological parameters during *Kharif* season 2022-23

3.1.1 Physico-chemical properties of the experimental plot

Soil samples were collected from each plot at a depth of 0-15 cm before sowing and after harvest. The samples were analyzed for different physical & chemical properties. The data on the initial status of the soil properties are presented below:

Table 3.2: Physico-chemical properties of the soil of experimental plot

Constituents	Value	Interpretation	Method of analysis
Mechanical analysis			
Sand (%)	53.00	Sandy clayloam	International pipette method (Piper, 1967)
Silt (%)	25.00		
Clay (%)	22.56		
Chemical analysis			
Soil pH	7.16	Neutral	Glass electric pH meter (Piper, 1967)
Organic carbon (%)	0.60	Medium	Walkey and Black rapid titration method (Walkey and Black, 1934)
Electrical conductivity (dS/m)	0.27	Normal	Solubridge method (Black, 1956)
Available N (kg/ha)	224	Low	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P ₂ O ₅ (kg/ha)	13.41	Medium	Calorimeter method (Olsen et al., 1954)
Available K ₂ O (kg/ha)	248	Medium	Flame photometer method (Chapman and Pratt, 1961)

The soil in the experimental field had a sandy clay loam texture, neutral in reaction (pH 7.16) with a medium OC content (0.60 percent), and EC (0.27 dS/m), and analyzed low in available nitrogen (224 kg/ha N), medium in available phosphorus (13.41 kg/ha P), and medium in available potassium (248 kg/ha K).

3.1.2 Cropping history of the experimental plot

In order to have a general idea of the cropping pattern of the experimental field since 2018.

Table 3.3: Cropping history of the experimental field

Year	<i>Kharif</i>	<i>Rabi</i>	<i>Zaid</i>
2019	Rice	Wheat	-
2020	Soybean	Wheat	-
2021	Soybean	Wheat	-

Note: The field was under the experiment on rice based cropping systems with fixed plots.

3.1.3 Experimental techniques

The field experiment consisted of six treatments and they were tested in randomized block design with four replications. The details of the treatments are given below:

Treatment No.	Nutrient Details
T ₁ Control	No addition of any inputs
T ₂ Natural farming practices	FYM@250kg/ha, Ghanjeevamrit@250kg/ha and Jeevamrit@ 500lit/ha.
T ₃ Organic farming practices	FYM@3.5t/ha Vermicompost @1.75t/ha, Neemcake @ 0.58 t/ha and 100kg rock phosphate
T ₄ INM practices (50% organic + 50% inorganic) NM with Brahmastra and Neemastra	FYM@2.33t/ha, Vermicompost @1.16t/ha, Neemcake@ 0.39t/ ha, N-35kg/ha, P-55kg/ha and K-18kg/ha
T ₅ INM practices (50% organic + 50% inorganic) NM with Need-based pesticides	FYM@2.33t/ha, Vermicompost @ 1.16t/ha, Neemcake@ 0.39 t/ha, N-35kg/ha, P-55kg/ha and K-18kg/ha
T ₆ 100 % Inorganic NM	Urea@43.5 kg/ha, SSP@375 kg/ha, MOP @ 33 kg/ha

Treatments	
T ₁	Control
T ₂ (NFP)	Natural farming practices (Beejamrit + Ghanjeevamrit + Jeevamrit, Mulching)
T ₃ (OFP)	Organic farming practices (FYM@3.5t/ha, VC@1.75t/ha, Neemcake@0.58t/ha)
T ₄ (INM+BN)	INM practices (50% organic + 50% inorganic NM) with Brahmastra and Neemastra
T ₅ (INM+NBP)	50% organic + 50% inorganic NM with need-based pesticides
T ₆ (IFP)	100% Inorganic farming practices

3.1.4 Variety details

Soybean (JS 20-98)

The variety has been developed by Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. This variety matures in 96-98 days and has the yield potential of 25-28 q/ha. It possesses Multiple resistant against Yellow Mosaic Virus and charcoal rot, blights, bacterial pustules and leaf spots as well as insect-pests. Especially, it is be more suitable for YMV and Charcoal Rot prone areas. It is suitable for timely sowing under medium to high rainfall conditions and medium to heavy soils.

Maize (JM-218)

The variety has been developed by Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. Suitable for rainfed condition in *kharif* and irrigated in *rabi* /summer.it mature in 94 days. It is tolerant to stem and root lodging and water logging conditions, highly responsive to fertilizers, tolerant to H. turcicum and H. maydis leaf blight, tolerant to stem borer.

3.1.5 Other experimental details

- Replications : 4
- Design : RBD
- Gross plot size : 12m x 10.80m
- Net plot size : 11m x 9.0 m
- Distance between replications : 2.0 m
- Distance between plots : 2.0 m
- Total number of plots : 24
- Rows spacing(common) : 30 cm
- Cropping system : Soybean + Maize (4:2 row ratio)
- Variety : Soybean JS 20-98, Maize JM-218
- Seed rate : 80 kg/ha, 20 kg/ha for soybean and Maize respectively
- Nutrient dose : As per treatments

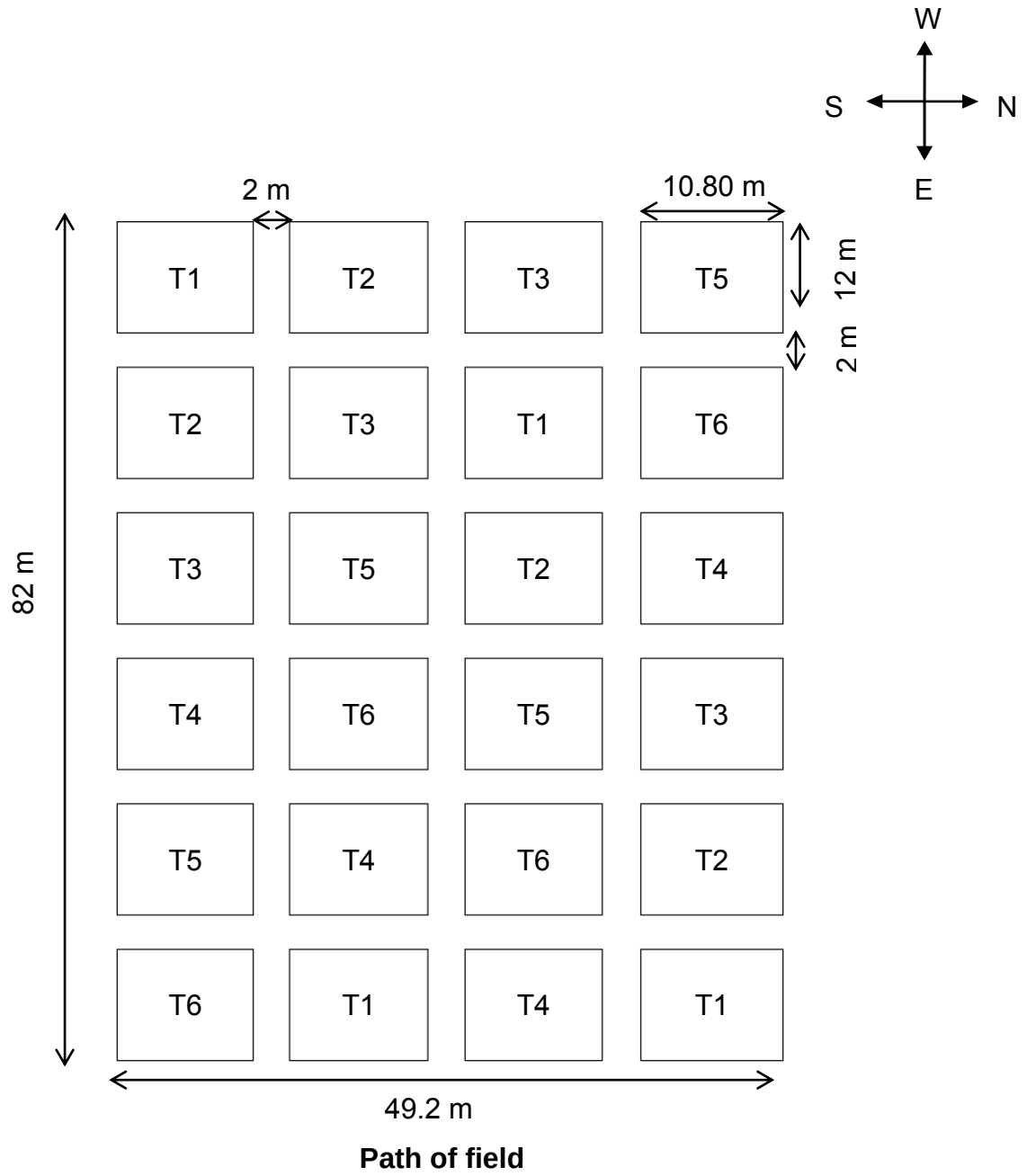


Fig. 3.2: Layout plan of experiment

Table 3.4: Details of different field operations done in soybean + maize intercropping during *Kharif*, 2022

S. No.	Field operation	Date	Remark
1	Land preparation	12/07/2022	Mechanically
2	Application of FYM, neem cake, vermicompost and ghanjeevamrit in respective treatments.	17/07/2022	Manually
3	Seed treatment with culture, beejamrit and fungicide in respective treatments	17/07/2022	Manually
4	Sowing of soybean and maize	17/07/2022	Manually
5	Weeding by hand hoe	10/08/2022	Manually
6	Jeevamrit spray in T ₂	12/08/2022	Manually
7	Hand weeding in T ₁ , T ₃ and T ₄	21/08/2022	Manually
8	Brahmastra spray in T ₂ , T ₃ and T ₄	21/08/2022	Manually
9	Preparation of drainage channels	01/09/2022	Manually
10	Neemastra spray in T ₂ , T ₃ and T ₄	08/09/2022	Manually
11	Jeevamrit spray in T ₂	12/09/2022	Manually
12	Herbicide spray in T ₆	03/09/2022	Manually
13	Harvesting of soybean and maize	26/10/2022	Manually
14	Soybean and maize threshing	1-5/11/2022	Manually
15	Sun drying of soybean and maize	8-10/11/2022	-

The date wise schedule of cultural operations performed in the field during investigation is presented in Table 3.4.

3.1.6 Land preparation

Ploughing followed by cross disc harrowing and levelling was done to prepare the field. Experiment layout was completed to suit the experimental design requirement. Before crop sowing, the recommended dosage of nutrients was applied to specific plots using manures and fertilizers.

3.1.7 Application of Manures and Fertilizers

N, P and K was applied through Urea, SSP, MOP, FYM, vermicompost, neemcake, jeevamrit and ghanjeevamrit as per treatments. Urea, SSP, MOP and DAP were applied in the open furrows before seed sowing. However, FYM, vermicompost, neemcake and ghanjeevamrit were applied at the time of final field preparation.

3.1.8 Seed treatment

Certified seed of crop variety were used in the experiment. Before sowing seed was treated with Trichoderma and Pseudomonas @ 5g/kg of seeds in OFP-T₃, INM+BN-T₄ and INM+NBP-T₅ treatments, beejamrit @3ml/kg seeds in NFP-T₂ treatments and with fungicide vitavax @ 2g/kg of seeds in IFP-T₆ treatments to protect the crop from soil and seed borne diseases and soil health maintenance.

3.1.9 Sowing of crop

Soybean cv. JS 20-98 and maize JM-218 was planted in 4:2 row ratio i.e., four rows of soybean followed by two row of maize each 30 cm apart. To maintain the required optimal plant population, 80kg/ha seed rate of soybean and 20kg/ha seed of maize on per hectare basis was taken and adjusted according to the area allotment was used. Seeds were sown in furrows manually at 2-3 cm deep and covered by a thin layer of soil.

Mulching

Mulching is done by the use of un-chopped paddy/wheat straw at the rate of 6t/ha in NFP-T₂ immediately after sowing of the crop as ground cover.

3.1.10 Weed control

In control plot two hand weeding were done to reduce crop weed competition while in natural farming plot no weeding were done because straw mulch is applied for this purpose. in case of integrated nutrient management plot i.e., T₃ and T₄ two hand weeding were done and in chemical plot imazethapyr@ 750ml/ha with one hand weeding were done to reduce crop-weed competition and to establish a favorable environment condition for crop development.

3.1.11 Insect and disease incidence

In order to protect crop from insect and pest alternate application of Brahmastra and Neemastra were done twice in each month from emergence to maturation of crop in treatment NFP-T2, OFP-T3 and INM+BN-T4 while in treatment INM+NBP-T5 and IFP-T6 chlorpyrifos@1.5lit/ha were used.

3.1.12 Harvesting

Prior to harvest the border rows in each plot were removed. Harvest of net plot in each plot was done separately. Soybean was harvested with the help of a sickle while maize cobs were picked manually. The harvested crop was dried on the field for 6 days. The bundles were tied and weighted individually after drying. The harvest from each plot was then transported to the threshing floor individually.

3.1.13 Threshing and winnowing

Crop obtained from the net plot area were conveyed on the threshing floor with labels to ensure their identity. All crop product (seeds/grains) were dried on the threshing floor. After that weighed with the electronic balance.

The seed/grain yield of crop was manually separated from the chaffs using a hand fan (Supa). Finally, on electronic balance, the weight of crop's cleanseed was recorded plot by plot.

3.2 Studies on crop

Pre harvest studies

3.2.1 Plant population (soybean and maize)

Plant population was recorded at 20 DAS and at harvest from one meter row length from 3 rows randomly in each plot and then averaged out and taken as plant population per meter row length.

3.2.2 Plant height (soybean and maize)

Three plants were chosen at random in each plot and tagged in order to take various observations. By the use of a meter scale, the height of the tagged plants was measured from the ground up to the base of the apical bud. Plant height was recorded at 30, 60, 90 DAS and harvest.

3.2.3 Branches/plant

The branches per plant were counted on the three tagged plants in each plot at 40, 60 DAS and harvest and then their mean was calculated for each treatment.

3.2.4 Numbers of effective root nodules/plant

From each border line three plants were uprooted at 40 and 60 DAS. for nodulation study, the plants from each treatment were uprooted with the help of a fork by removing the entire roots along with soil lump and then were kept in bucket, filled with water for half an hour. The roots of each plant were then gently cleaned carefully so that nodules are not separated from roots. After that, all the nodules were removed from the roots and pressed between two fingers for assessing the presence of leg-hemoglobin so as to know the effective nodules. Thereafter, the total number of effective nodules / plants was counted and mean was worked out.

3.2.5 Dry weight of effective nodules/ plant

After the recording of number of effective nodules, these nodules were kept in oven for purpose of drying of nodules at 60°C temperature for 3 days. After the drying of nodules their dry weight were calculated at 40 and 60 DAS.

3.2.6 Leaf area index (LAI) (soybean and maize)

Three matured leaves from the upper, middle, and bottom portions of three different plants were randomly selected from each treatment at 30 and 60 DAS. Leaf area was measured by Leaf Area Meter which was multiplied by the number of leaves per plant and thereafter mean leaf area per plant was determined. Thereafter, leaf area index was calculated by the formula given by Gardner et al. (1985)

$$LAI = \frac{(LA_2 + LA_1)}{2} / P$$

Where,

A₁ = Leaf area of 1st sampling

A₂ = Leaf area of 2nd sampling

P = Ground area

3.2.7 Dry matter production (g plant⁻¹) (soybean and maize)

Three randomly selected plants from each border line were sampled out at 30, 60, 90 DAS and at harvest for both the crops. These plants were oven dried at 70°C till constant weight was attained. These were averaged for recording dry matter accumulation as g plant⁻¹.

3.3 Post harvest studies

3.3.1 Main crop (Soybean)

3.3.1.1 Number of pods per plant:

The pods of five randomly selected plants were counted at crop maturity to determine the average number of pods per plant.

3.3.1.2 Number of seeds per pod:

Grain number of ten randomly selected pods were counted at crop maturity to determine the average number of seeds per pod.

3.3.1.3 Test weight (g):

Composite grain samples were drawn from produce of each plot. From this 1000 grain were counted and weighed on an electric top pan balance.

3.3.1.4 Seed yield (kg ha⁻¹):

Weight of grains per net plot was recorded and then converted to kg ha⁻¹.

3.3.1.5 Stover yield (kg ha⁻¹):

After removing the grains from the total produce. The remain was sun dried and weighted for each net plot and then converted into kg ha⁻¹.

3.3.1.6 Biological yield (kg ha⁻¹):

The grain & straw produce obtained from each net plot was drying added and considered as biological yield/plot.

3.3.1.7 Harvest index (%):

Harvest index was calculated by using the following formula (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} \times 100$$

3.3.2 Companion crop (Maize)

3.3.2.1 Number of cobs per plant:

Number of cobs of the five tagged plants were counted at harvest and the mean value per plant under each experimental unit was worked out.

3.3.2.2 Length of cob (cm):

The length of three cobs selected randomly from the net plot was measured by the use of scale and then their mean length was calculated.

3.3.2.4 Girth of cob (cm):

The girth of three random cobs from the net plot is measured by the use of measuring tape after picking and their mean girth is calculated.

3.3.2.5 Number of seeds per cob:

The cobs of three tagged plants were shelled after sun drying. Total number of grains were counted and average was calculated.

3.3.2.6 Seed index (g):

The sun dried 100 grains were counted for recording the seed index in grams.

3.3.2.7 Grain yield (kg ha⁻¹):

Total grain produce from each net plot was cleaned, dried, weighed and recorded and then converted in terms of kg ha⁻¹.

3.3.2.8 Stover yield (kg ha⁻¹):

The stover left after removing the cobs was harvested, sun dried and then weighed to obtain the stover yield. It was converted to kg ha⁻¹.

3.3.2.9 Biological yield (kg ha⁻¹):

The grain & straw produce obtained from each net plot was drying added and considered as biological yield/plot.

3.3.2.10 Harvest index (%):

Harvest index was calculated by using the same formula as was used in case of soybean.

3.3.3 Soybean equivalent yield (kg/ha⁻¹):

Soybean Equivalent yield under different treatments was calculated by converting the grain yield of maize into soybean yield considering MSP of soybean (Rs.43 kg⁻¹) and maize (Rs. 19.62 kg⁻¹) with the help of the formula for each plot.

$$SEY = \frac{\text{Yield of maize (Kg/ha)} \times \text{Price of maize (Rs/kg)}}{\text{Price of soybean (Rs/kg)}} + \text{yield of soybean(kg/ha)}$$

3.4 Economics of the treatments

To establish the economics of treatments, the economics of various treatments were estimated on a per hectare area basis in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR), and benefit-cost ratio (B:C ratio)

3.4.1 Cost of cultivation

To estimate the economics of treatments or the cost of cultivation, the cost of various agro inputs, including laborer charges for raising crop under each treatment, was employed. The cost of cultivation for each crop component was determined individually, and the values of all crop components were combined to get the cost of cultivation for that particular treatment/crop.

3.4.2 Gross monetary returns

The gross monetary returns (GMR) obtained from the crop received under each treatment were calculated using the local market price of the produce (both seed and stover). The GMR of each crop component was determined separately and then summed up the values of produce from all crops. This GMR represents the GMR per hectare under various treatments.

3.4.3 Net monetary returns

The net monetary returns (NMR) per hectare under each treatment from various crops were determined as below:

$$NMR \text{ (Rs/ha)} = \{GMR \text{ (Rs/ha) of a treatment} - \text{Cost of cultivation (Rs/ha) of the same treatment}\}$$

3.4.4 Benefit cost ratio or profitability

The benefit cost ratio is an index that indicates the monetary gains over

each rupee of investment under various treatments. It is also known as profitability, and it is determined by using the formula:

$$\text{B:C Ratio} = \frac{\text{Gross monetary returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

3.5 Statistical analysis of treatment

Utilizing the methods of the analysis of variance, data collected from diverse observations were tabulated and statistically analyzed (Panse and Sukhatme, 1967). The significance of the treatments was assessed using the "F" test, and when "F" most clearly illustrated the importance, the critical difference (C. D.) at 5% level of significance was used to assess the difference between the treatments.

Table 3.5: Skeleton for analysis of variance (ANOVA)

Source of variance	d.f.	SS	MSS	F"Value"		
				Calculated	Tabulated	
					5%	1%
Replication	(r-1) = 3	RSS	RMSr	RMSe		
		d.f.		EMSe		
Treatment	(t-1) = 5	TSS	TMSt	TMSt		
		d.f.		EMSe		
Error	(r-1) (t-1) = 15	ESS	EMSe			
		d.f.				
Total	(rt-1) = 23	Total SS				

The significant differences between different treatments were judged by using critical differences (C.D.) which was calculated as follows:

Critical difference (CD) = t. x SE(d)

$$\text{SE (d)} = \frac{\sqrt{2EMS}}{r}$$

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

where,

SSE = Error sum of square

SST	=	Total sum of square
MSR	=	Replication mean sum of square
MST	=	Treatment means sum of square
S.Ed	=	Standard error of differences between two treatments
SEm	=	Standard error of mean
MSE	=	Error mean sum of square i.e., Error variance
t (0.05)	=	Tabulated "t" Value at error degree of freedom at p=0.05
C.D	=	Critical difference (For treatments at 5%)
C.V	=	Coefficient of variation

Chapter - IV

RESULT

RESULT

The present research, named “**Studies on the performance of soybean + maize intercropping (4:2 row ratio) under different farming systems**” was conducted during *kharif* 2022 at Instructional Research farm Krishi Nagar JNKVV, Jabalpur (M.P). The experimental data was recorded periodically and statistically analysed. The results are presented in the tabular form and illustrated through bar graph wherever it was required.

4.1 Plant population

The data for plant population was recorded at 20 DAS and harvest of crop. Data (Table 4.1) and illustrated in fig 4.1 and 4.2 showed that the nutrient management practices in soybean + maize intercropping had non-significant influence on plant population at both the stages.

Table 4.1: Plant population/m² of soybean under different treatments

Treatments	Plant population per meter row length			
	soybean		Maize	
	20DAS	harvest	20DAS	harvest
T1 - CONTROL	15.15	12.27	10.07	9.46
T2 - NFP	15.24	12.39	10.38	9.66
T3 - OFP	15.74	13.17	10.67	10.38
T4 - INM+BN	16.97	14.59	11.55	11.03
T5 - INM+NBP	16.61	13.95	10.95	10.46
T6 - IFP	16.17	13.85	11.24	10.54
SEm±	1.05	0.77	0.77	0.70
CD	NS	NS	NS	NS

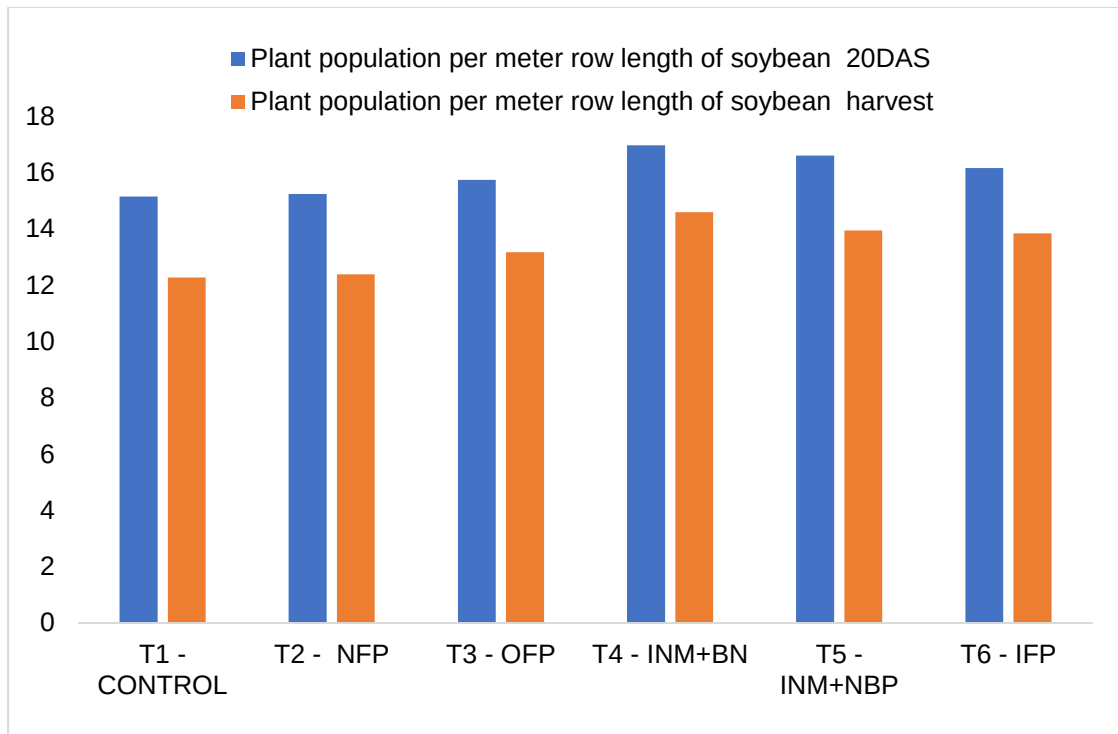


Fig 4.1: Plant population per meter row length of soybean

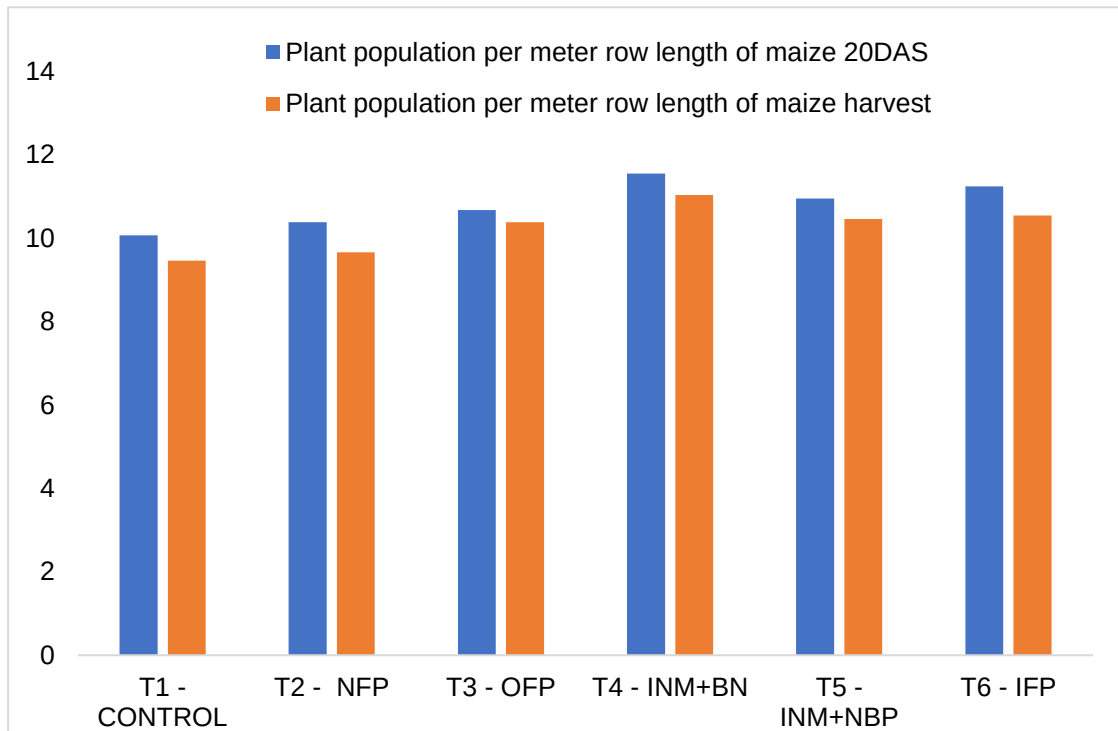


Fig 4.2: Plant population per meter row length of maize

4.2 Plant height

The data pertaining to plant height of maize and soybean as influenced by different treatments are presented in Table 4.2 and depicted in fig 4.3 and 4.4. The increase in plant height was rapid during early crop growth stages while diminishing increase was observed in later stages but the trend of variation among different treatments was the same. Finally at harvest Integrated nutrient management with Brahmastra and Neemastra (T4 – INM+BN) recorded highest plant height of soybean i.e. 50.08 cm which was at par with treatment under Integrated nutrient management with need based pesticides INM+NBP-T5, IFP-T6, OFP-T3 and NFP-T2. Irrespective of period of observation, significantly minimum plant height was recorded under Control-T₁ (31, 38.10, 38.50, 39.23 cm) at 30, 60, 90 DAS and harvest respectively.

In case of maize Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) recorded maximum plant height (57.83, 160.25, 190.49, 191.03cm) at 30, 60, 90 DAS and harvest respectively. However, T₆ (inorganic farming practices,) was found at par with (INM + BN-T4) in maize at all stages, while significant difference was observed in other treatments. Minimum plant height (46.91, 142.19, 153.62, 154.28 cm) was recorded at 30, 60, 90 DAS and harvest under T₁ control.

Table 4.2: Plant height of soybean + maize under different treatments

Treatments	Plant height(cm)							
	Soybean				Maize			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
T1 - Control	31.00	38.10	38.50	39.23	46.91	142.19	153.62	154.28
T2 - NFP	31.75	41.71	42.70	43.34	51.15	143.53	157.70	158.25
T3 - OFP	32.56	43.75	44.08	44.78	52.38	145.99	159.48	160.05
T4 - INM+BN	36.58	49.01	49.20	50.08	57.83	160.25	190.49	191.03
T5 - INM+NBP	34.08	45.75	47.75	48.67	53.36	146.83	169.30	169.88
T6 - IFP	32.58	45.36	45.28	46.22	55.04	156.08	180.72	181.18
SEm±	1.59	2.01	2.03	2.13	2.06	4.94	8.51	8.48
CD	4.79	6.06	6.13	6.42	6.21	14.91	25.64	25.55

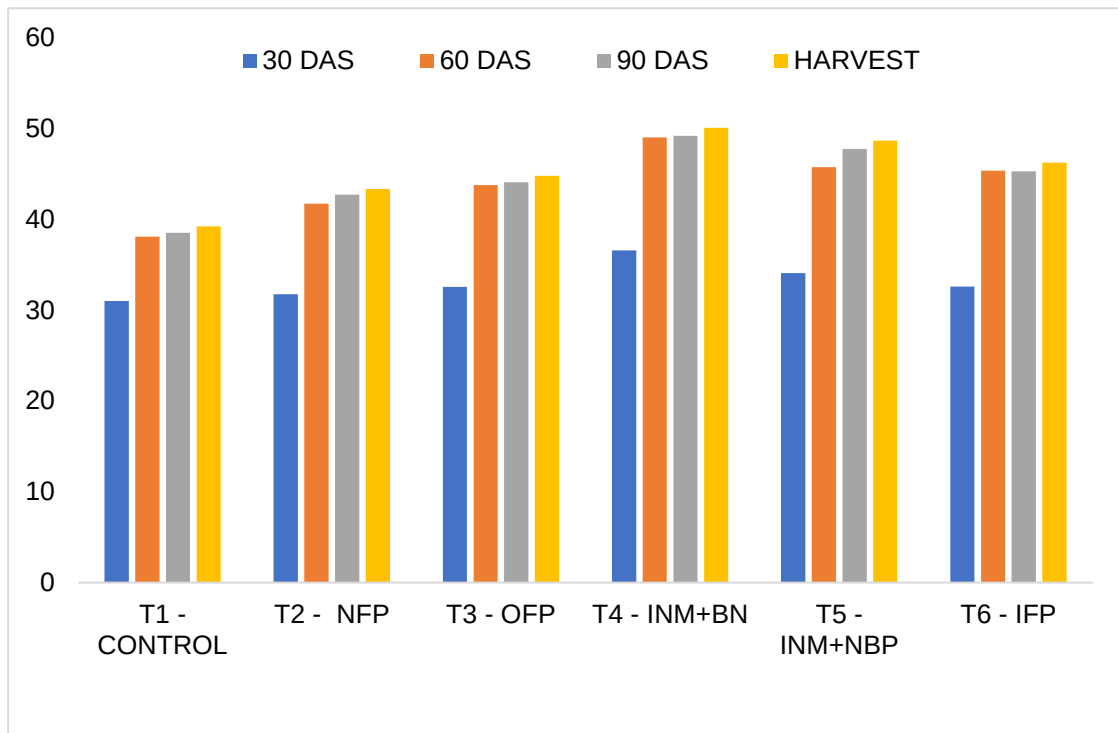


Fig 4.3: Plant height of soybean at different intervals

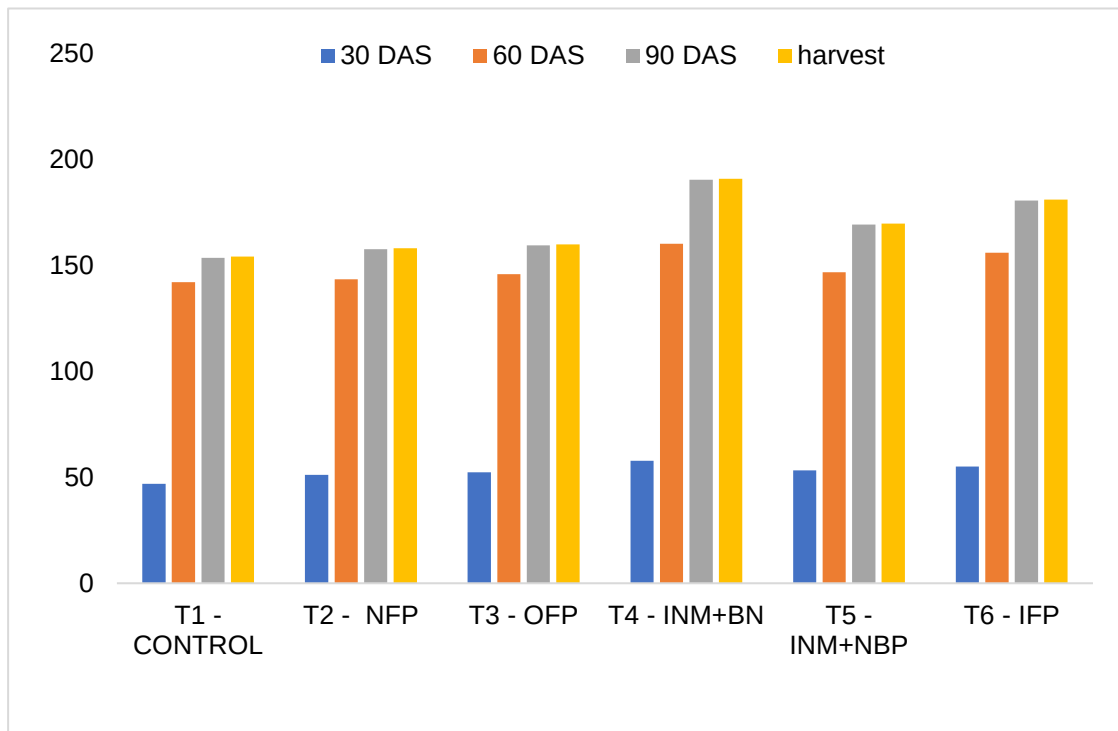


Fig 4.4: Plant height of maize at different intervals

4.3 Branches per plant

Data on branches per plant at 30,60 DAS and harvest are presented in Table 4.3 and depicted in fig 4.5. In general, branches per plant increased up to 60 DAS. Treatment of Integrated nutrient management with Brahmastra and Neemastra(T4 – INM+BN) in soybean resulted in significantly higher (5.01,6.65) branches per plant at 30 and 60 DAS respectively. Moreover, INM+NBP-T5 was found at par with, INM+BN-T4 followed by IFP-T6, OFP-T3, NFP-T2 respectively. Lowest number of branches (3.52,4.50) per plant was recorded in (control-T1).

Table 4.3: Branches per plant of soybean under different treatments

Treatments	Branches per plant		
	Soybean		
	30DAS	60DAS	Harvest
T1 - Control	3.52	4.50	3.55
T2 - NFP	3.83	5.05	4.38
T3 - OFP	3.89	5.40	4.65
T4 - INM+BN	5.01	6.65	5.93
T5 - INM+NBP	4.87	6.50	5.83
T6 - IFP	4.09	6.10	5.55
SEm±	0.25	0.32	0.32
CD	0.77	0.96	0.96

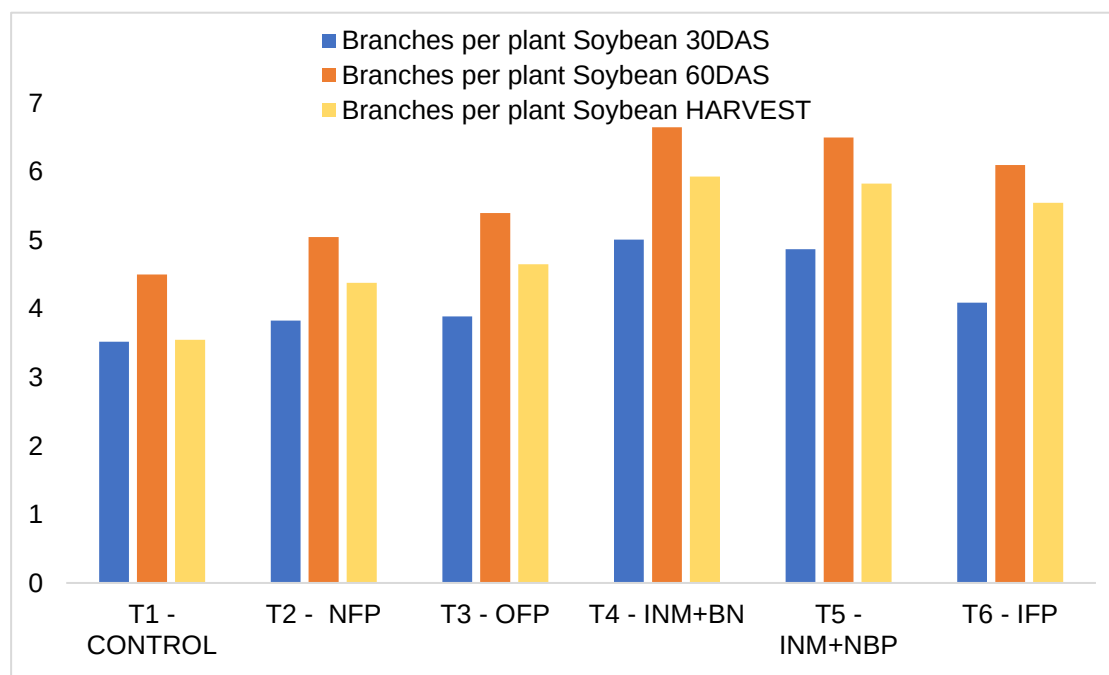


Fig 4.5: Branches per plant of soybean at different intervals

4.4 Number of root nodules per plant

The data on Number of root nodules/plant at 30 and 60 DAS presented in Table 4.4 showed significant difference under different treatments. The maximum number of root nodules (40.29,47.99/plant) were observed in T₃ (OFP) which was at par with INM+NBP-T₅ (37.90, 46.51/plant) followed by INM+BN-T₄, IFP-T₆ and NFP-T₂. The lowest number was recorded in case of Control-T₁ (32.73, 39.65/plant) at 30 and 60 DAS respectively.

Table 4.4: Number of root nodules/plant of soybean influenced under different treatments

Treatments	Root nodules per plant	
	Soybean	
	30DAS	60DAS
T1 - Control	32.73	39.65
T2 - NFP	36.63	40.48
T3 - OFP	40.29	47.99
T4 - INM+BN	37.13	44.69
T5 - INM+NBP	37.90	46.51
T6 - IFP	37.92	45.86
SEm±	2.15	2.44
CD	6.48	7.36

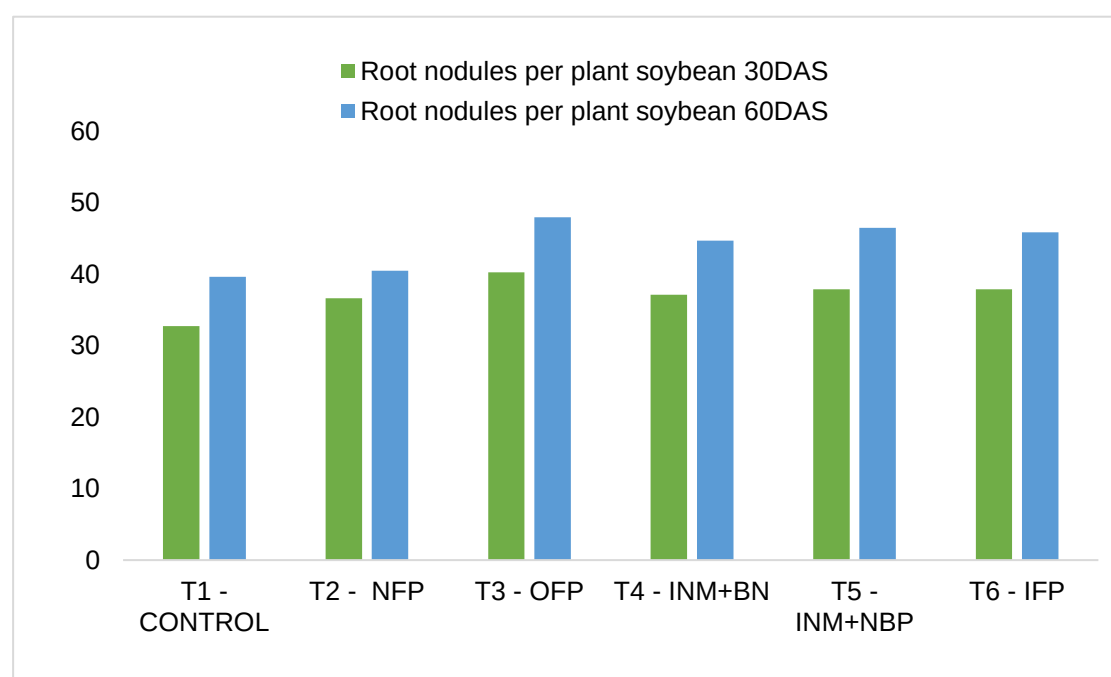


Fig 4.6: Root nodules per plant of soybean at different intervals

4.5 Dry weight of root nodules per plant

The data on dry weight of root nodules at 30 and 60 DAS as presented in Table 4.5 and illustrated in fig 4.7. showed significant variation due to treatments. The highest dry weight (0.46, 0.58 g) was recorded in treatment T3(OFP) at 30 and 60 DAS, respectively, which was at par with T4 but significantly superior over other treatments.

Table 4.5: Dry weight of root nodules/plant of soybean influenced under different treatments

Treatments	Dry weight (g) of root nodules per plant	
	Soybean	
	30DAS	60DAS
T1 - Control	0.32	0.40
T2 - NFP	0.35	0.49
T3 - OFP	0.46	0.58
T4 - INM+BN	0.37	0.50
T5 - INM+NBP	0.41	0.54
T6 - IFP	0.40	0.52
SEm±	0.03	0.02
CD	0.09	0.07

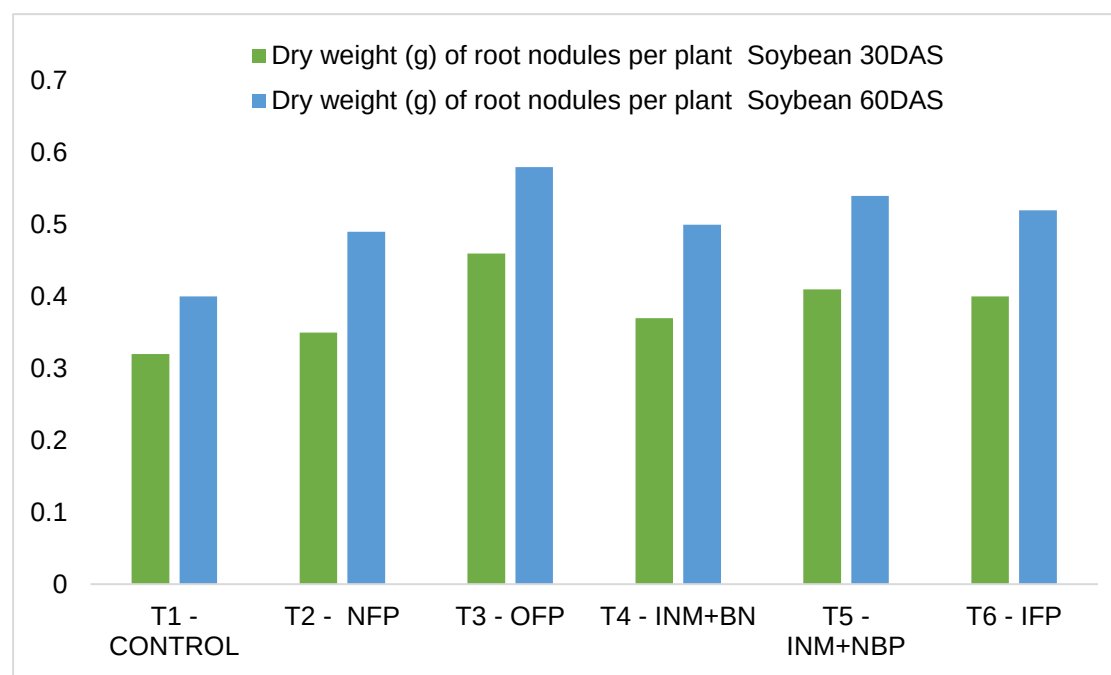


Fig 4.7: Dry weight (g) of root nodules per plant of soybean at different intervals

4.6 Leaf area index

Data pertaining to leaf area index in soybean + maize intercropping has been presented in Table 4.6 and depicted in fig 4.8, 4.9. Highest leaf area index (1.9, 4.61) of soybean was obtained in Integrated nutrient management with Brahmastra and Neemastra (T4 – INM+BN) at 30 and 60 DAS. It was found at par with T5- INM+NBP (1.7,4.31) at 30 and 60 DAS respectively.

However, in case of maize highest leaf area index (2.62, 8.13) was recorded in Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) at 30 and 60 DAS respectively which was found at par with IFP-T6 followed by INM+NBP-T5. Lowest LAI (2.21,6.48) was observed in Control-T1.

Table 4.6: LAI of soybean + maize influenced under different treatments

Treatments	LAI			
	Soybean		Maize	
	30 DAS	60 DAS	30 DAS	60 DAS
T1 - CONTROL	1.43	3.7	2.21	6.48
T2 - NFP	1.62	3.81	2.27	7.28
T3 - OFP	1.65	3.95	2.31	7.65
T4 - INM+BN	1.90	4.61	2.62	8.13
T5 - INM+NBP	1.70	4.31	2.37	7.85
T6 - IFP	1.69	4.10	2.45	8.03
SEm±	0.12	0.17	0.09	0.26
CD	0.36	0.51	0.26	0.79

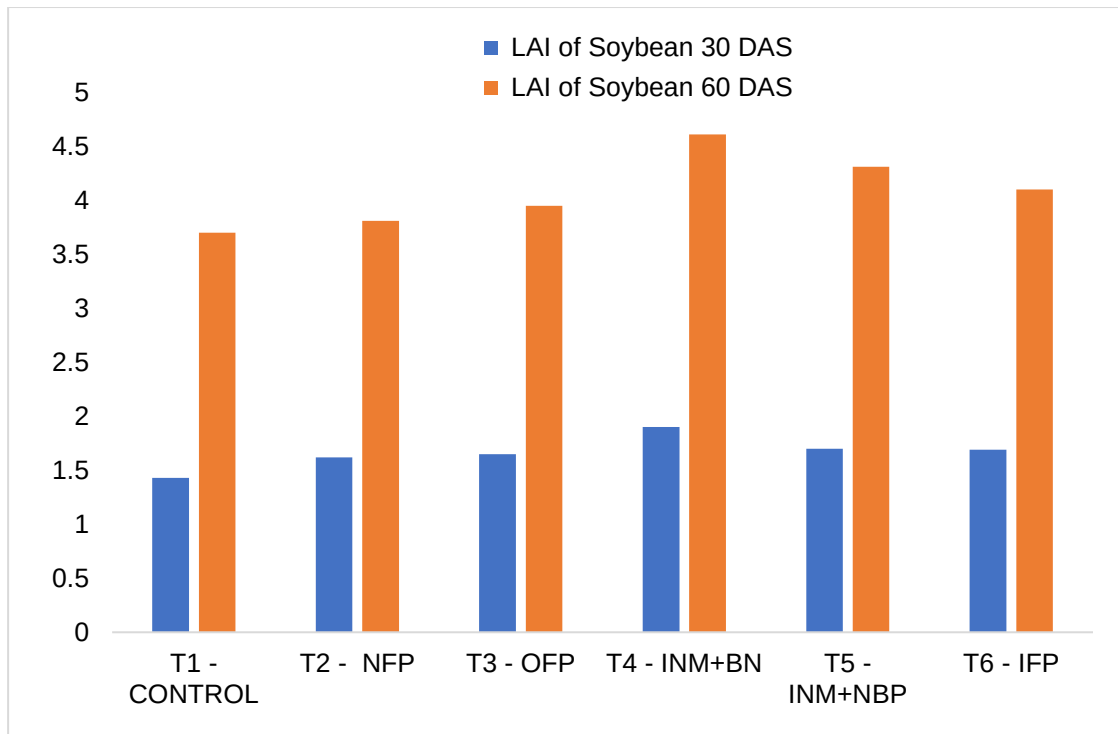


Fig 4.8: LAI of soybean at different intervals

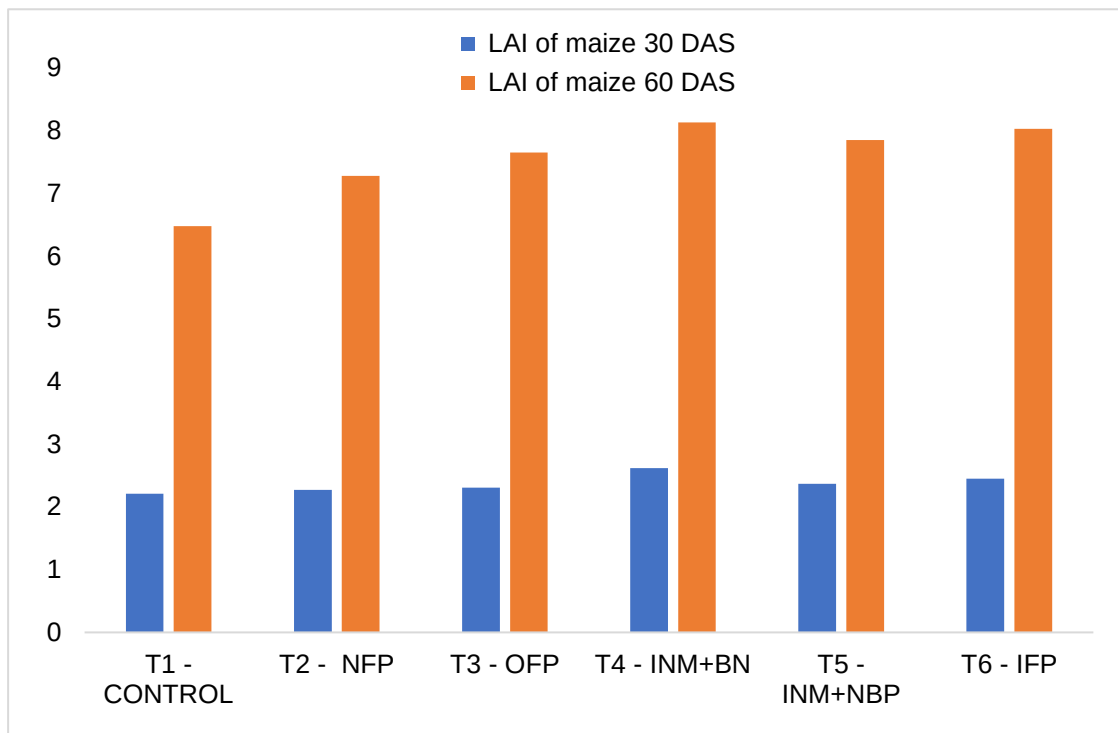


Fig 4.9: LAI of maize at different intervals

4.7 Dry matter production

The data on dry matter production (g/plant) of soybean and maize individually at 30,60,90 DAS and harvest are presented in Table 4.7 and illustrated in fig 4.10 and 4.11. Experimental data indicated that the dry matter production increased with the increase in the crop growth stages. There was a continuous increase in dry matter production with advanced stage of the crop up to harvest. Among the different treatments Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) gave the highest dry matter production in soybean (3.47, 10.90, 35.10 and 32.18g) at 30 ,60, 90 DAS and harvest respectively. However, INM+BN-T4 was found at par with INM+NBP-T5 followed by IFP-T6 while it proved superior over all other treatments in soybean. the lowest dry matter production (2.81, 9.29, 26.63 and 27.35g) was observed in control-T1 at 30,60,90 DAS and harvest respectively.

In case of maize application of Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) gave the highest dry matter production (16.31, 122.31, 235.79 and 255.79g) at 30,60,90 DAS and harvest respectively. Lowest dry matter production (14.84, 102.38, 200.75 and 217.15g) was recorded in control-T1 at 30, 60, 90 DAS and harvest respectively.

Table 4.7: Dry matter production of soybean + maize influenced under different treatments

Treatments	Dry matter production (g/plant)							
	Soybean				Maize			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
T1 - CONTROL	2.81	9.29	26.63	27.35	14.84	102.38	200.75	217.15
T2 - NFP	2.94	9.51	29.50	30.18	15.16	112.15	218.02	235.22
T3 - OFP	3.06	9.75	29.98	30.55	15.23	114.62	225.41	242.81
T4 - INM+BN	3.47	10.90	35.10	32.18	16.31	122.31	235.79	255.79
T5 - INM+NBP	3.20	10.48	30.55	29.98	15.28	115.77	230.14	247.94
T6 - IFP	3.15	10.16	30.18	29.50	15.77	119.87	233.50	252.00
SEM±	0.12	0.33	0.91	0.92	0.56	4.1	7.71	7.86
CD (0.05%)	0.37	0.99	2.76	2.77	(NS)	12.36	23.32	24.5

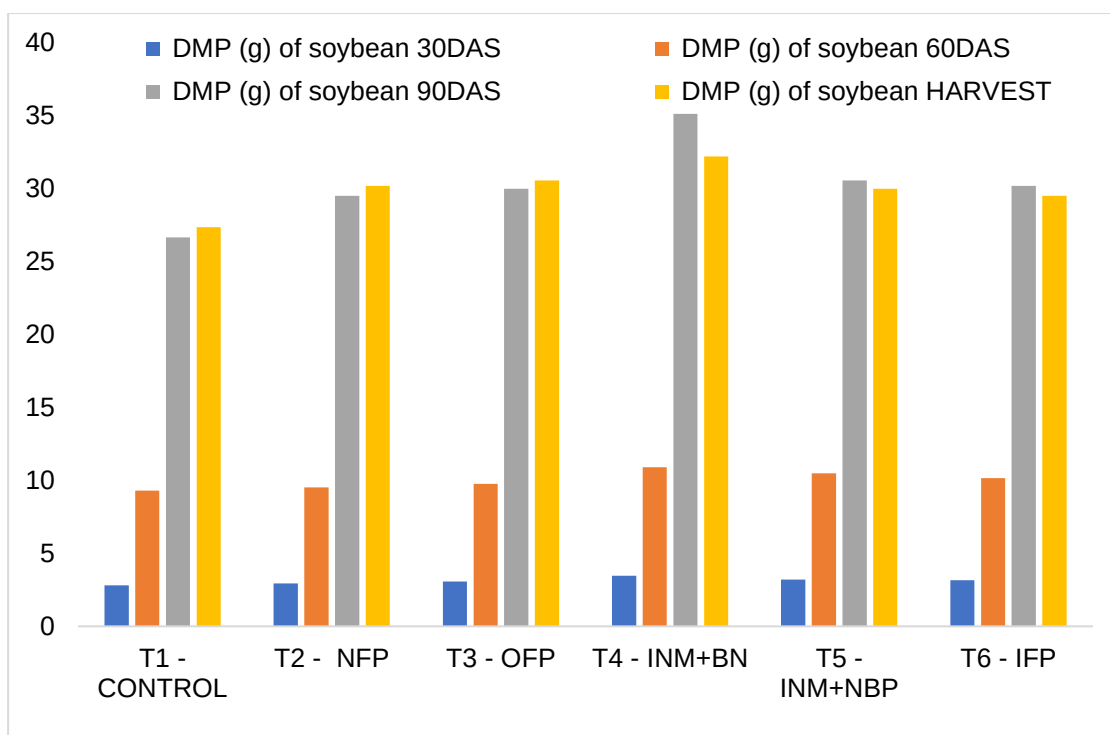


Fig 4.10: Dry matter production (g) of soybean

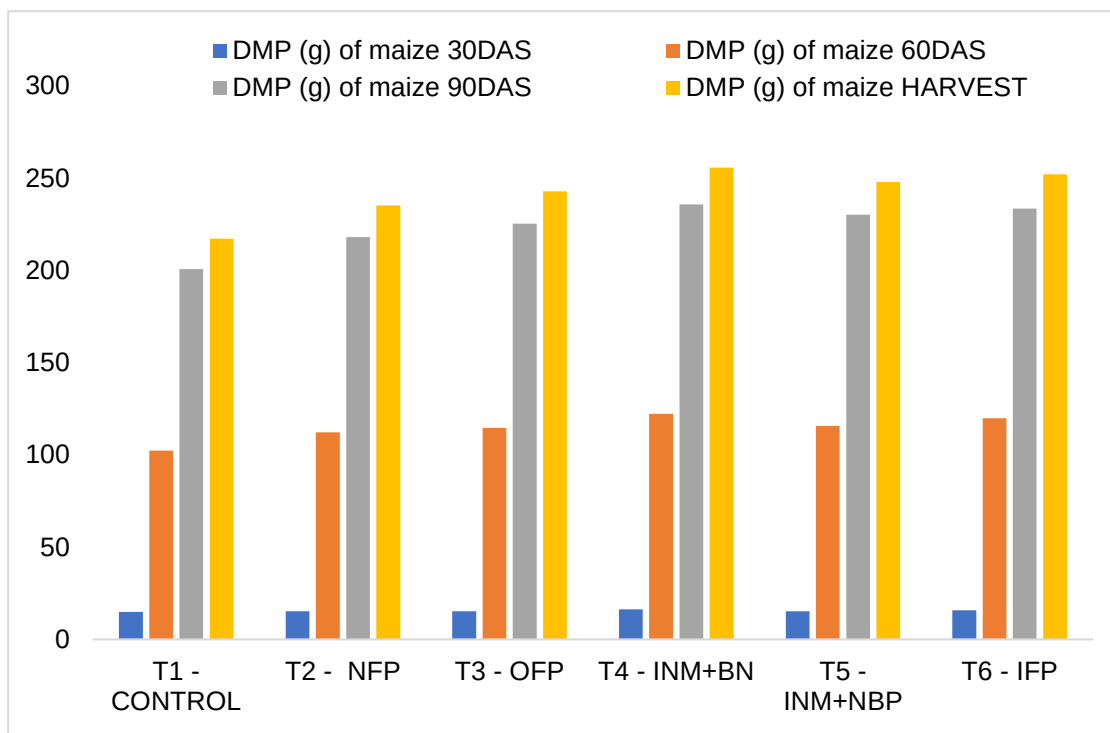


Fig 4.11: Dry matter production (g) of maize

4.8 Yield attributes:-

4.8.1 Pods per plant (soybean)

Data on pods per plant under soybean + maize intercropping is presented in Table 4.8 and depicted in fig 4.12, indicated that application of Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) produced higher number of pods 48.66 pods/plant which was at par with INM+NBP-T5 and proved equally good with IFP-T6 and OFP-T3. However, it proved superior over NFP-T2, while the lowest pods per plant (42.89) were counted in Control-T1.

4.8.2 Seeds per pod (soybean)

The number of seeds per pod were counted and statistically presented in Table 4.8. Data showed non-significant effect of various nutrient management treatments on seeds per pod. However, the seeds per pod varied from (2.86-2.58).

4.8.3 Test weight (soybean)

Test weight of 1000 seeds was recorded and statistically analysed and presented in Table 4.8. Among different treatments the maximum test weight (107.87 g) was recorded in Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) which was statistically similar with INM+NBP-T5, IFP-T6, OFP-T3 and NFP-T2. However, it was significantly superior over Control-T1.

Table 4.8: Number of pods/plants, seeds/pod and test weight of soybean under different treatments at harvest

Treatments	Yield attributes		
	Soybean		
	Pods/Plant	Seeds/pod	Test WT(g)
T1 - Control	42.89	2.58	95.06
T2 - NFP	44.71	2.65	102.40
T3 - OFP	45.44	2.75	102.58
T4 - INM+BN	48.66	2.86	107.87
T5 - INM+NBP	47.84	2.80	101.37
T6 - IFP	46.18	2.80	100.48
SEm±	1.86	0.08	2.59
CD(0.05%)	5.62	NS	7.77

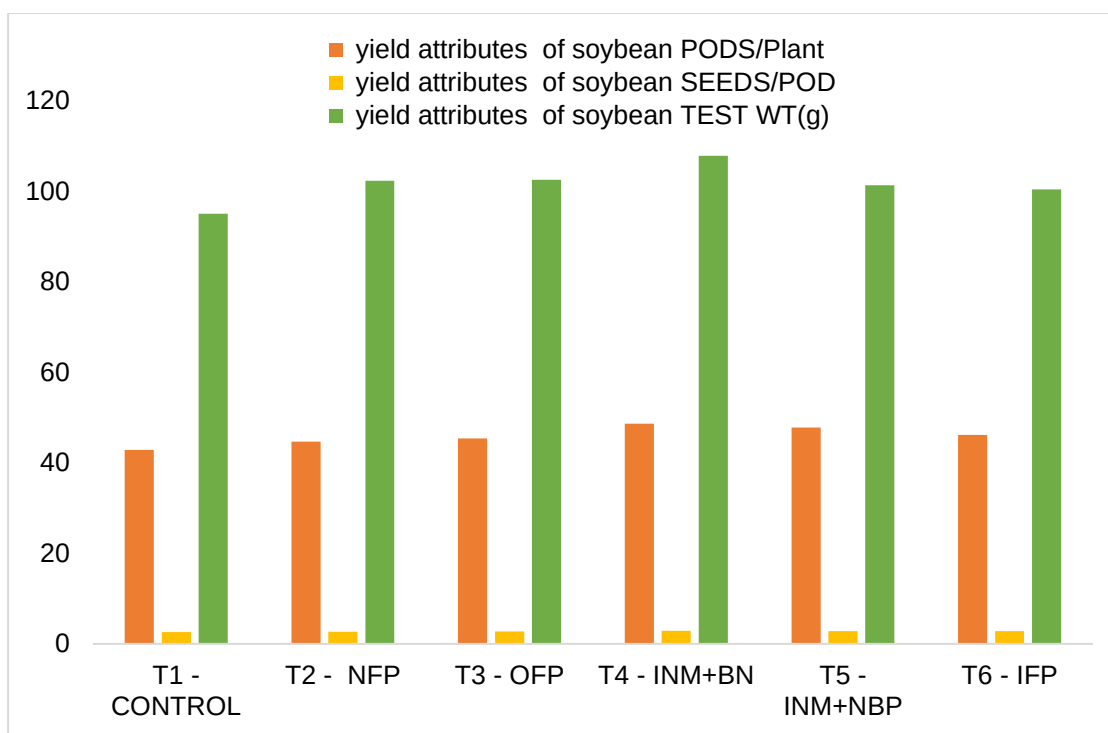


Fig 4.12: Yield attributes of soybean

4.8.4 Cobs per plant (maize)

The effect of different treatments on cobs per plant in maize were recorded and statistically analysed. Data presented in Table 4.9 showed that no significant difference in cobs per plant was found in all the treatments.

4.8.5 Cob length (maize)

The cob length was measured and the average cob length was statistically calculated. The data presented in Table 4.9 showed that application of Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4) recorded significantly higher (14.25 cm) cob length. However, it was at par with INM+NBP-T5 followed by IFP-T6 and OFP-T3. Lowest cob length (11.83 cm) was measured in Control-T1.

4.8.6 Cob girth (maize)

The data presented in Table 4.9 showed that the application of different nutrient management practices significantly affected cob girth (cm). Highest cob girth (13.16 cm) was measured in Integrated nutrient management with Brahmastra and Neemastra (INM+BN-T4). However, it was at par with all

other treatments. Moreover, it proved statistically superior over all other treatment. Lowest cob girth (11.92 cm) was measured in Control-T1.

4.8.7 Cob weight (maize)

The data in relation to cob weight was recorded and presented in Table 4.9. The application of different nutrient management practices showed significant effect on cob weight. Highest cob weight (87.17 g) was measured in INM+BN-T4 which was at par with all other treatments. However, it proved significantly superior over T1. Lowest cob weight (71.15g) was measured in Control-T1.

4.8.9 Seeds/ cob (maize)

The average count of seeds per cob was calculated and presented in Table 4.9. Among different treatments highest seeds/cob (346) were counted in INM+BN-T4. It was found at par with IFP-T6 followed by INM+NBP-T5 and OFP-T3. However, lowest seeds per cob (249) was recorded in control-T1.

4.8.10 Seed index (maize)

The data presented in Table 4.9 showed significant difference in seed index (g) in different treatments. The highest seed index (19.77g) was measured in INM+BN-T4 which was at par with IFP-T6, INM+NBP-T5, and OFP-T3. Lowest seed index (17.03g) was found in Control-T1.

Table 4.9: Cobs/plant, cob length, cob girth, cob weight, seeds/cob and seed index of maize under different treatments at harvest

Treatments	Yield attributes					
	Maize					
	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Cob weight (g)	No of seeds/ cob	Seed index(g)
T1 - Control	1.2	11.83	11.92	71.15	248	17.03
T2 - NFP	1.3	12.08	12.42	75.16	266	17.38
T3 - OFP	1.4	13.00	12.67	79.48	289	18.04
T4 - INM+BN	1.8	14.25	13.16	87.17	346	19.77
T5 - INM+NBP	1.7	13.25	12.91	83.11	301	18.28
T6 - IFP	1.7	13.25	13.00	85.30	316	18.81
SEm±	0.63	0.75	0.32	4.76	20.04	0.76
CD(0.05%)	NS	2.25	0.96	14.36	60.12	2.28

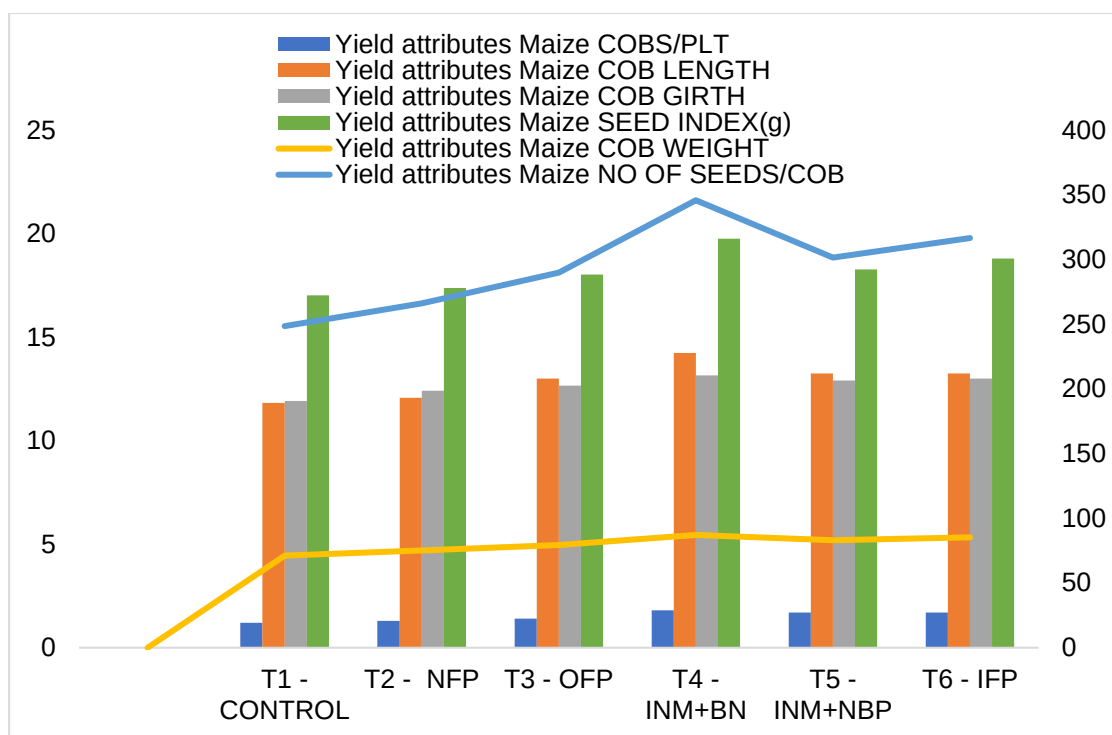


Fig 4.13: Yield attributes of maize

4.9.1 Seed yield (kg/ha)

The treatment wise data was recorded and statistically calculated and presented in Table 4.10 and depicted in fig 4.14 and 4.15. The data on seed yield/ha of soybean showed significant difference under treatments. Among different treatment significantly higher seed yield 1414 kg/ha was recorded in INM+BN-T4 followed by 1383 kg/ha in INM+NBP-T5. However, significantly lower seed yield 711.11 kg/ha was recorded in Control-T1.

Analysis of data showed significant variation in seed yield of maize due to different treatments. Further it was observed that the treatment INM+BN-T4 produced significantly higher yield of 1536 kg/ha which was at par with INM+NBP-T5 and IFP-T6. The significantly lowest yield of 1117 kg/ha was noted under Control-T1.

4.9.2 Stover yield (kg/ha)

The data related to stover yield after statistically calculated and presented in Table 4.10 and illustrated in fig 4.14 and 4.15. It showed that stover yield is significantly influenced under all treatments. Among different treatments the significantly higher stover yield 3166 kg/ha was recorded in

INM+BN-T₄, which is at par with T₅ 3068 kg/ha (INM+NBP). The significantly lower stover yield 1443 kg/ha was recorded in T₁ (control).

The analysis data indicated significant differences in stover yield of maize under different treatments. The highest stover yield of 3440 kg/ha was recorded under INM+BN-T₄ which was at par with IFP-T₆ followed by INM+NBP-T₅. However, significantly lowest stover yield 2280 kg/ha was obtained in Control-T₁

4.9.3 Soybean equivalent yield (kg/ha)

Soybean equivalent yield represents the total productivity of the cropping system which showed significant improvement due to intercropping with maize. Growing of soybean with maize in replacement series produced significantly higher soybean equivalent yield. The data presented in Table 4.12 shows the variation due to application of different nutrient management treatments. Significantly higher soybean equivalent yield 2114 kg/ha was obtained in T₄ (INM+BN) which was at par with T₆ (IFP) followed by T₅ (INM+NBP). However, lowest SEY (1221 kg/ha) was obtained in T₁ (control).

Table 4.10: Seed yield, stover yield and SEY (kg/ha) of soybean + maize under different treatments

Treatments	Yields (Kg/ha)				
	Soybean		Maize		SEY
	Seed	Stover	Seed	Stover	
T1 - Control	711	1843	1117	2280	1221
T2 - NFP	998	2404	1238	2798	1563
T3 - OFP	1171	2539	1341	2991	1783
T4 - INM+BN	1414	3166	1536	3440	2114
T5 - INM+NBP	1383	3068	1442	2962	2041
T6 - IFP	1256	2747	1488	3043	1937
SEm±	59.23	133.42	58.41	168.76	76.53
CD (0.05%)	178.53	402.18	176.07	508.7	230.68

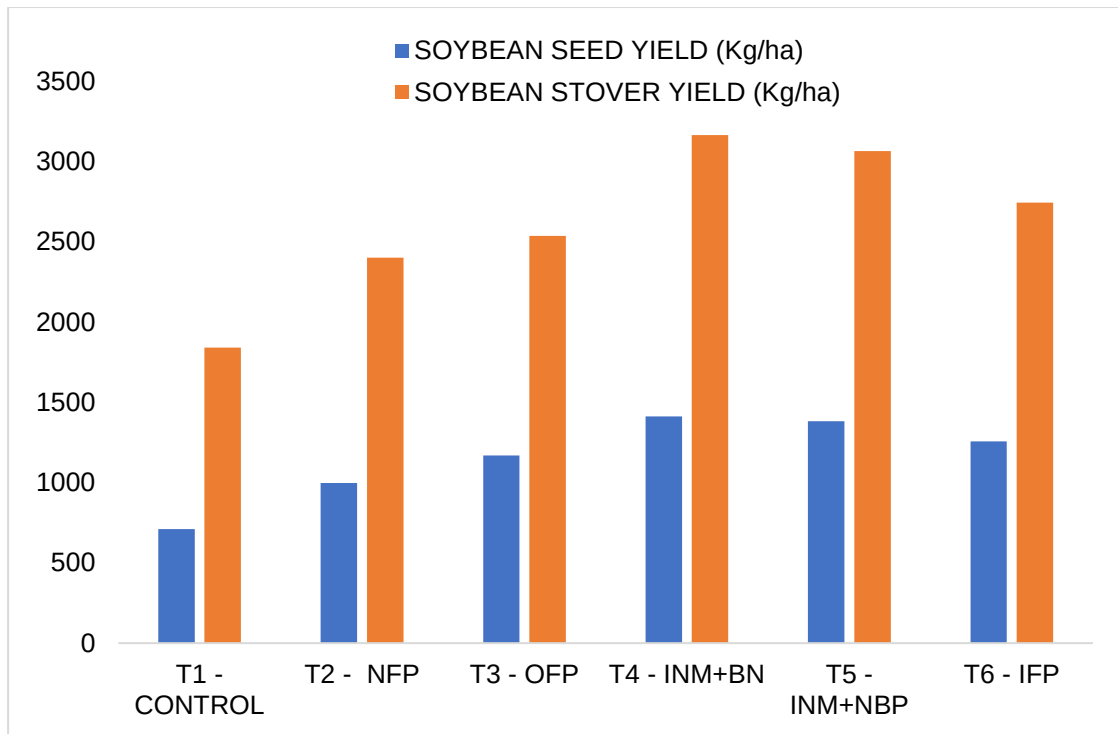


Fig 4.14: seed and stover yield of soybean

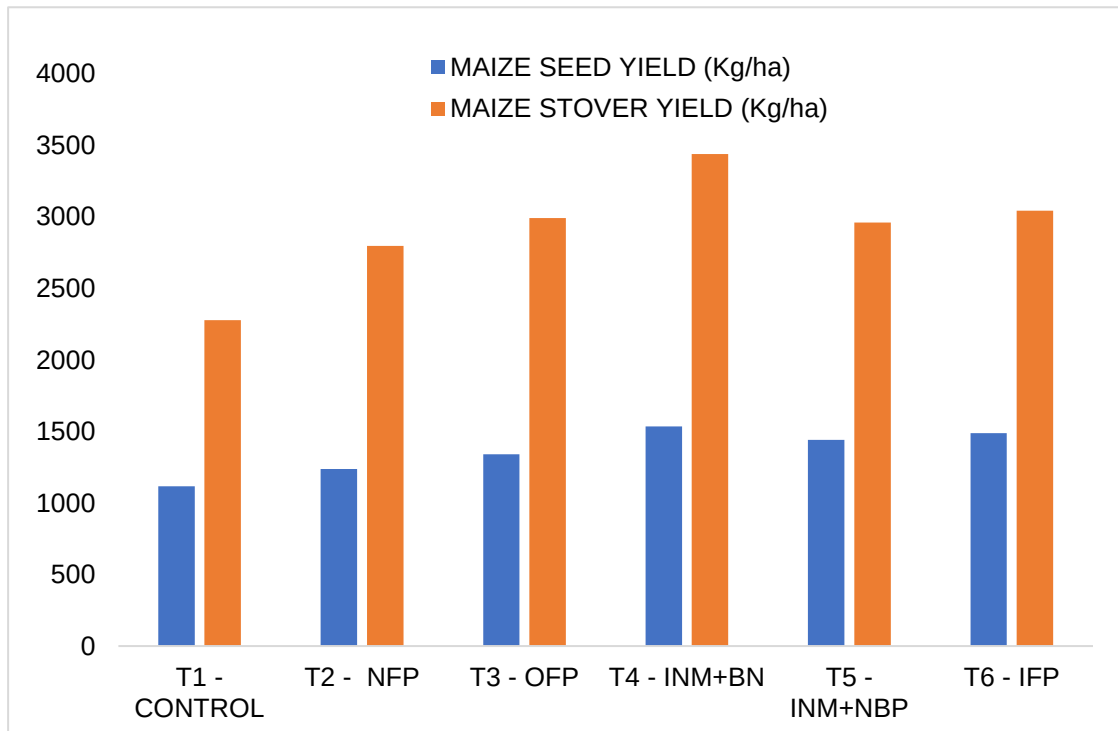


Fig 4.15: Seed and stover yield of maize

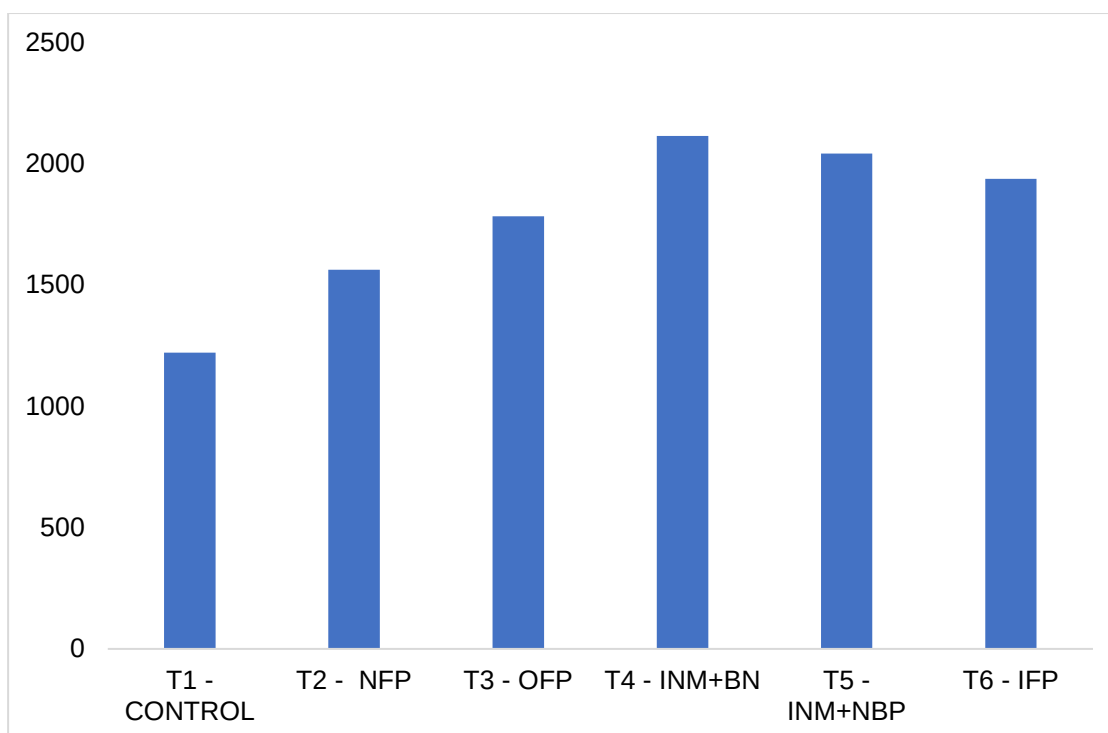


Fig 4.16: Soybean equivalent yield

4.9.3 Harvest index (%)

The data pertaining to harvest index as influenced by different treatments are presented in Table 4.11. T3 (OFP) recorded higher harvest index of soybean (31.56). Moreover, lowest harvest index (29.34) was observed in T2 (NFP). In case of maize (T6- IFP) gave the highest (33.06) harvest index while lowest HI (30.67) was observed in T2-NFP.

Table 4.11: Harvest index of soybean + maize under different treatments

Treatments	Harvest index (%)	
	Soybean	Maize
T1 - Control	31.03	32.89
T2 - NFP	29.34	30.67
T3 - OFP	31.56	30.96
T4 - INM+BN	30.86	30.86
T5 - INM+NBP	31.06	32.88
T6 - IFP	31.44	33.06
SEm±	0.15	0.52
CD(0.05%)	0.45	1.58

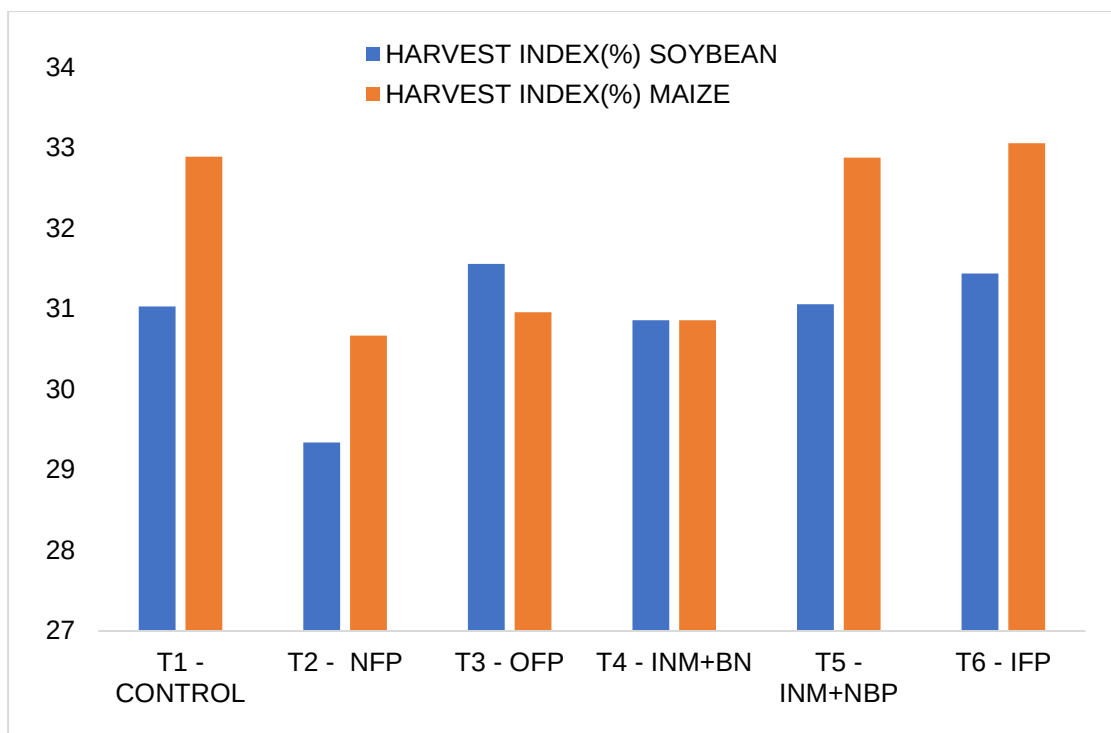


Fig 4.17: Harvest Index of soybean and maize

4.10 Changes in chemical properties of soil

Data related to various soil chemical properties such as pH, EC, OC and available N, P and K contents were recorded before sowing and after harvest of crop under different treatments presented in Table 4.12. It is clear from the results that soil pH slightly reduced in treatments T₁ to T₅ and increased in T₆ as compared to initial status of soil. In case of EC and OC of soil under different treatments did not record any significant changes but in case of available N, P and K of soil showed significant difference under different treatments with increased values from initial soil status.

Table 4.12: Chemical properties of soil under different treatments

Treatment No.	pH	EC (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
T ₁ Control	7.11	0.29	0.60	226.75	13.20	260.12
T ₂ NFP	7.12	0.30	0.61	233.50	13.26	260.64
T ₃ OFP	7.13	0.33	0.67	254.25	13.35	269.42
T ₄ INM+NB	7.13	0.31	0.62	246.50	13.40	268.50
T ₅ INM+NBP	7.12	0.32	0.61	246.25	13.47	263.00
T ₆ IFP	7.17	0.31	0.59	236.00	13.28	266.54
Initial status of soil	7.16	0.27	0.60	222.46	13.41	248
SEm±	0.09	0.01	0.01	1.37	0.02	1.88
CD (5%)	0.27	NS	NS	4.12	0.06	5.65

4.11 Economics of soybean maize intercropping system under different treatments

Economic returns were analysed with the help of input cost of individual treatment and cost of production. The data obtained have been presented in Table 4.13 and illustrated in fig 4.18.

4.11.1 Cost of cultivation

Data pertaining to cost of cultivation was presented in Table 4.13. The data showed that the lowest cost of cultivation was estimated in T₁ (control). The cost increased in the range of Rs 28533 to Rs 51571 with the variations in the treatments. However, the highest cost was found in OFP-T₃ which was Rs. 51571.

4.11.2 Gross returns

Data related to gross return obtained in different treatments of soybean maize intercropping is presented in Table 4.13. The data reveal that the maximum gross return Rs 102413 was obtained in INM+BN-T₄ followed by INM+NBP-T₅ (Rs 97605). However, lowest gross return (Rs 58806) was obtained in T₁ (control).

4.11.3 Net returns

The data from Table 4.13 showed significant difference in net returns in soybean and maize intercropping under different treatments. Among the treatments, IFP-T6 registered highest net returns (64821 Rs. ha⁻¹) followed by INM+NBP-T5 (55306 Rs ha⁻¹). The lowest net returns (30223 Rs. ha⁻¹) were estimated in T1 (control).

4.11.4 Benefit- cost ratio

The data presented in Table 4.13 shows that T6 (inorganic crop management) gave the highest benefit- cost ratio 3.20. However, the lowest B:C ratio (1.67) was computed in T3 (organic farming practices).

Table 4.13: Economics under different treatments

Treatments	Cost of Cultivation (Rs/ha)	GMR (Rs/ha)	NMR (Rs/ha)	B:C ratio
T1 - Control	28583	58806	30223	2.06
T2 - NFP	35941	76231	40290	2.12
T3 - OFP	51571	86235	34664	1.67
T4 - INM+BN	47549	102413	54864	2.15
T5 - INM+NBP	42299	97605	55306	2.30
T6 - IFP	28773	92294	63521	3.20

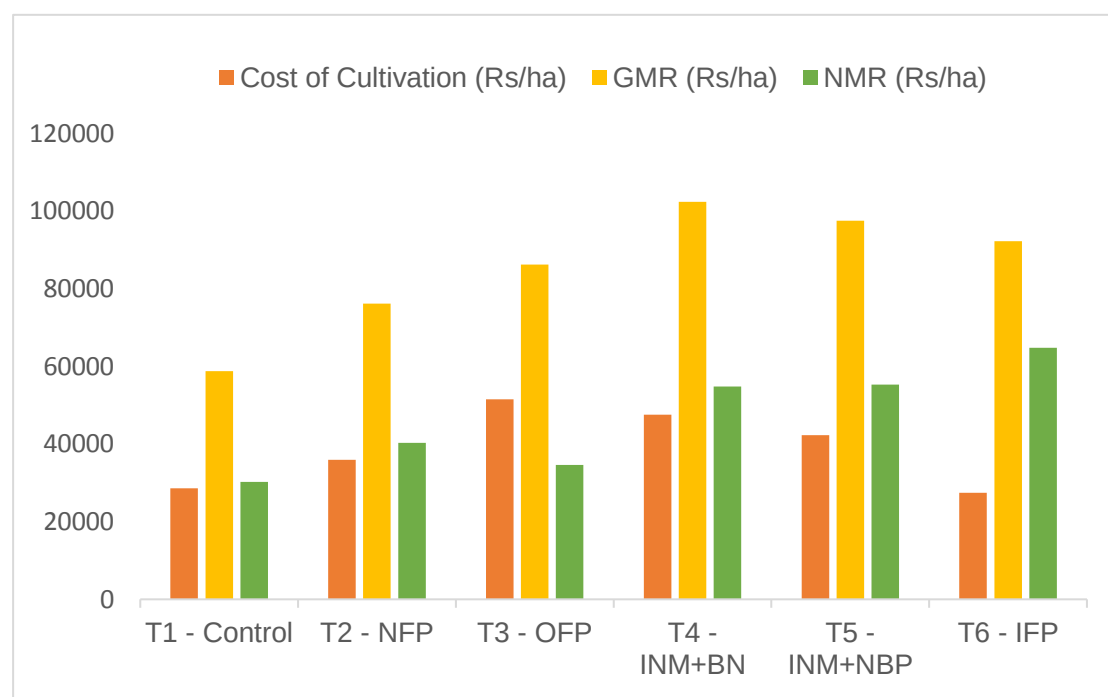


Fig 4.18: Economics of the treatments



**View of Experimental field of Soybean + maize intercrop during kharif
(2022)**



Control – T₁



Natural farming practices – T₂



Organic farming practices –T₃



Integrated nutrient management with Brahmastra and Neemastra – T₄



Integrated nutrient management with Need based pesticide – T₅



Inorganic farming Practices – T₆

Chapter – V

DISCUSSION

DISCUSSION

The present investigation entitled “**Studies on the performance of soybean + maize intercropping (4:2 row ratio) under different farming systems**” was conducted during *kharif* season 2022-23. The significant findings have been discussed and properly explained based on agronomic principles and findings of other research workers.

Weather conditions

The weather data presented in Table 3.1 during the current investigation for the crop growing season shows consistent patterns with typical climatic values. The maximum weekly temperature ranged from 29.0°C to 42.8°C, while the minimum weekly temperature ranged from 12.6°C to 29.1°C. In the morning, the maximum relative humidity varied from 64.0% to 93%, and in the evening, it ranged from 39% to 79%. Throughout the crop growing season, the crop received a total of 115.6 hours of sunlight, with sunshine hours ranging from 0.2 to 8.2 hours per day. The total seasonal rainfall recorded was 1443.7 mm, which occurred over 57 wet days. These weather conditions are suitable for proper growth and development of crops.

Growth parameters

The different growth parameter *i.e.*, plant height, number of branches/plants, leaf area index, root nodules/plant, dry weight (g) per plant, dry matter accumulation of soybean and maize differed significantly due to different treatments at various crop growth stages.

Data presented in Table 4.1 showed that the plant population/m² of soybean and maize was not influenced significantly by different treatments at both the stages of observation which indicate that none of the treatments had adverse effect on germination and plant stand.

The data on plant height of soybean and maize as influenced by different treatments presented in Table 4.2. revealed that among different treatments Integrated nutrient management with Brahmastra and Neemastra (INM+BN), Integrated nutrient management with need-based pesticide (INM+NBP), Inorganic farming practices (IFP), Organic farming practices (OFP) recorded significant increase in plant height of soybean, (the values of

final plant height being 50.08, 48.67, 46.22 and 44.78 cm respectively) as compared to control(39.23cm). Increase in the height of soybean under these treatments could be attributed to the supply of nutrients through organic sources i.e. FYM & vermicompost which might have improved soil micro climatic conditions favoring plants growth. Similar results have been reported by Gupta *et al.* (2003), Devi *et al.* (2013).

In case of maize INM+BN-T4 recorded highest plant height which was at par with IFP-T₆ and INM+NBP-T5 while significant difference was observed in other treatments. In this case the organic manures have obviously favoured plant growth and instant availability of nitrogen through urea could have favoured the plant height. The results are in conformity to that reported by Mahmood *et al.* (2017).

The data presented in Table 4.3 indicate that the number of branches/plants was found significantly higher under INM+BN-T4 followed by INM+NBP-T5. The increase in the number of branches per plant under these treatments might be due to combined application of different organic manures i.e., FYM and vermicompost under INM+BN-T₄ which would have enhanced better growth and development ultimately a greater number of branches per plant. These results are in close agreement to those observed by Sutar *et al.* (2015), Wailare *et al.*, (2017) and Gowthamchand *et al.*, (2018).

The data presented in Table 4.4 showed that root nodules per plant varied significantly under different treatments. The highest number of root nodules (40.29, 47.99/plant at 30 and 60 DAS respectively) was observed in OFP-T3 which was at par with INM+BN-T4(37.13, 44.69) followed by INM-NBP- T₅(37.90, 46.51) and IFP-T6(37.92, 45.86). This could be attributed to organic inputs which maintain proper moisture and aeration in soil, which facilitate the vigorous root system and enhances the microbial activity in the soil (Gajbhiye *et al.* 2009). Similar results were reported by Devi *et al.*, (2013)

LAI was significantly affected due to different treatments (Table 4.) Highest leaf area index of soybean (1.9, 4.61 cm² at 30 and 60 DAS respectively) was obtained in INM+BN-T4. It was found at par with INM+NBP-T5(1.7, 4.31cm²) followed by IFP-T6(1.69, 4.12cm²). The minimum LAI (1.43, 3.7cm²) was recorded under control-T₁ at 30 and 60 DAS. The synergistic

effect of inorganic and organic nutrients might have favoured crop growth and gave higher number of leaves and higher leaf area and ultimately the LAI. These results are in conformity to that reported by Khan *et al.*, (2009), Saxena *et al.* (2001) and Gupta *et al.* (2003).

In case of maize highest leaf area index (2.62, 8.13cm² at 30 and 60 DAS respectively) was recorded in INM+BN-T4 which was found at par with IFP-T6(2.45, 8.03) followed by INM+NBP-T5(2.37, 7.85), this might be due to fertilizer source that fulfilled the nutrient requirements at all growth stages which improved photosynthesis, thereby enhancing the vigorous growth of leaves. These results are in conformity to that reported by Baradhan *et al.*, 2018.

Data related to dry weight per plant of soybean and maize as influenced by different treatments presented in Table 4.7 revealed that the treatment of INM+BN-T4 produced the highest dry matter in soybean (3.47, 10.90, 35.10 and 32.18 g/plant at 30 ,60, 90 DAS and at harvest respectively) which can be attributed to the vigorous growth of soybean under congenial environment and availability of nutrients through different organic sources i.e. FYM, Vermicompost and Neemcake and inorganic sources i.e. Urea, SSP and MOP. These results are in conformity to that reported by Gupta *et al.*, (2003) and Aher *et al.* (2019).

In case of maize treatment INM+BN-T4 gave the highest dry matter production (16.31, 122.31, 235.79 and 255.79 g/plant at 30,60,90 DAS and harvest respectively) which might be due to reasons mentioned above for soybean. These results are in conformity to that reported by Baradhan *et al.*, (2018) and Jain *et al.*, (2022).

Yield attributing characters

The Data on pods per plant of soybean under soybean + maize intercropping presented in Table 4.8, indicated that treatment INM+BN-T4 produced the highest number of pods (48.66 pods/plant) which was at par with INM+NBP-T5(47.84), IFP-T6(46.18), OFP-T3(45.44) and NFP-T2(44.71). It is due to adequate nutrients availability in balance amount during entire crop growth period which improved various growth parameters i.e., plant

height, number of leaves, branches and leaf area which finally increased the LAI and this subsequently increased the number of pods per plant of soybean. These results are in conformity to that reported by Sharma *et al.* (2005), Dikshit and Khatik (2002) and Kannan *et al.*, (2013).

Data presented in Table 4.8 showed that the number of seeds per pod was not influenced significantly by different treatments.

The data in relation to test weight (1000-seed weight) of soybean as influenced by different treatments are given in Table 4.8 showed that the maximum test weight (107.87 g) was recorded in INM+BN-T4. The better availability of macro and micronutrients in the soil under these treatments favoured the growth and development at all stages of soybean which finally resulted in enhancing the seed weight (Jawadagi *et al.*, 2012). These results are in conformity to that reported by Devi *et al.* (2013) and Khare *et al.* (2016)

Number of cobs per plant in maize

Data from Table 4.9 showed that the number of cobs per plant was not influenced significantly by different nutrient management treatments.

Cob weight, girth, length and seeds per cob in maize

Data presented in Table 4.9 showed significant effect of different treatments on cob weight, girth and length. The treatment INM+BN-T4 recorded higher cob length (14.25 cm), cob girth (13.16 cm), cob weight (87.17 g) and seeds/cob (346) which is at par with INM+NBP-T5 followed by IFP-T6, OFP-T3 and NFP-T2. Enhanced growth parameters i.e., plant height, number of leaves, and LAI, which increases the biomass accumulation in the maize plant resulted in increased in cob weight, girth and length of cob per plant and finally the seeds per cob in maize. These findings are in conformity to that reported by Singh *et al.* (1988). Similar findings were given by Jat *et al.*, 2014

Seed yield, stover yield and SEY

Data in relation to seed and stover yield (kg/ha) of soybean as influenced by different treatments are presented in Table 4.10. The highest seed yield was observed under INM+BN (1414 kg/ha) which was at par with

INM+NBP (1383 kg/ha) followed by IFP (1258 kg/ ha). Similar trend was followed in case of soybean stover yield, the highest stover yield was observed in INM+BN (3166 kg/ha) which was at par with INM+NBP (3068 kg/ha). Balanced amount of nutrients through various organic and inorganic sources increased the growth parameters i.e., plant height, number of leaves, branches and LAI which in turn increased the number of pods per plant, seeds per pod and test weight of soybean and ultimately the seed yield. As the yield is positively correlated with the yield attributes. The results appear to be justified. These findings are similar with the results of Aher *et al.* 2012 and Macchar *et al.* (2012).

Data on seed and stover yield of maize under different treatments (table 4.10) showed that the treatment INM+BN-T4 produced significantly higher seed yield (1536 kg/ha) which was at par with IFP-T6(1488kg/ha) followed by INM+NBP-T5(1442 kg/ha). While in case of maize stover, maximum stover was observed under INM+BN-T4(3440 kg/ha) which was at par with IFP-T6(3043 kg/ha) followed by INM+NBP-T5(2962 kg/ha) and OFP-T3(2991 kg/ha). It is notable that OFP gave significant increase in stover but not the seed yield as compared to control, which can be on account of continued vegetative growth till maturity. Balanced amount of nutrients through various organic and inorganic sources increased the growth parameters i.e., plant height, number of leaves, and LAI which in turn increased the yield attributing parameters i.e., cob weight, cob girth, cob length and seeds per cob and ultimately the seed yield. As the yield is positively correlated with the yield attributes. These findings are in close conformity with the results of Walia *et al.*, 2021 and Das *et al.*, 2023

Data on soybean equivalent yield under different treatments (table 4.10) showed that the treatment INM+BN (2114 kg/ha) showed the highest yield which was at par with INM+NBP (2041 kg/ha) followed by IFP (1937 kg/ha). this might be due to in INM+BN highest seed yield was observed in both soybean and maize. The balanced and continuous supply of nutrients during crop growth period under INM+BN resulted in higher yield of soybean and maize. Further, enhanced nutrient supply resulted in better plant growth and improved synthesis and translocation of metabolites to various

reproductive structures and improved distribution metabolites in grains leads to higher grain yield.

Harvest index

The data on harvest index as influenced by different treatments are presented in Table 4.11. OFP-T3(31.56) recorded higher harvest index of soybean This might be due to better nutrient uptake which increased biomass production thereby enhancing source sink relationship (Aher *et al.* 2012). These findings are in close conformity with the results of Dikshit and Khatik (2002) and Khare *et al.* (2016).

In case of maize the highest HI was observed under IFP-T6(33.06). this could be due to immediate availability of nutrients supplied by inorganic fertilizers which enhanced the uptake of nutrients that was responsible for better source-sink relationship in maize. These findings are in close conformity with the results of Walia *et al.*, 2021

Soil properties

The data (Table 4.12) showed that significant effect in pH, N, P, K content was recorded and maximum found under T4 (INM+BN) and T5 (INM+NBP) but there was no significant effect on EC and OC as recorded after crop harvest. The significant increase in available N content of soil might be due to increased mineralization of organic N due to lower C:N ratios in soil. The combined organic and inorganic manures, enhanced higher nitrogen availability due to addition of chemical fertilizer along with organic manures and its retention in the soil, which is consistent with lower rates of N losses than C losses during organic manure degradation (Chen *et al.*, 2010). These results are in agreement with the findings of Mahmood *et al.*, 2017 and Choudhary *et al.*, (2023).

Economic viability of the treatments

Economic analysis of treatments was recorded on per hectare area basis, which includes cost of cultivation, gross monetary return, net monetary return and benefit-cost ratio as affected by various treatments (Table 4.13).

Data pertaining to cost of cultivation showed that the lowest cost of

cultivation was estimated in control-T1 (28583). The cost increased in the range of Rs 28583 to Rs 51571 with the variations in the treatments. However, the highest cost was incurred in OFP-T3 which was Rs. 51571. The higher cost of cultivation with OFP was also reported by Bachhav and colleagues (2010) and Chandel et al., (2010).

Data pertaining to gross return obtained under different treatments of soybean + maize intercropping is presented in Table 4.13. The data reveal that the maximum gross return Rs 102413 was obtained in INM+BN-T4 followed by INM+NBP-T5(Rs 97605), IFP-T6(Rs. 92294), OFP-T3(Rs. 86235) and NFP-T2(Rs. 76231). The lowest gross return (Rs 58806) was obtained in control-T1. These findings are in close conformity with the results of Ramesh *et al.* (2010), and Ramesh *et al.* (2010).

Among different treatments, IFP-T6 registered highest net returns (63521 Rs. ha⁻¹) followed by INM+BN-T4(54306 Rs ha⁻¹), INM+NBP-T5(54306 Rs ha⁻¹), NFP-T2(40290 Rs ha⁻¹) and OFP-T3(34664 Rs ha⁻¹). The lowest net returns (30223 Rs. ha⁻¹) was estimated in control-T1. Similar results were presented by Raveena et al., (2023) and Shwetha *et al.* (2008).

The data presented in Table 4.13 shows that IFP-T6 gave the highest benefit- cost ratio 3.20. The lowest B:C ratio (1.67) was computed in T3 (organic farming practices). This was due to higher cost of cultivation in organic farming while in inorganic farming practices the cost of cultivation was lower compare to all other treatments. These results are in with close agreement those of Yadav *et al.* (2009) and Das *et al.*, (2023).

Chapter – VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

SUMMARY, CONCLUSIONS AND SUGGESTIONS

FOR FURTHER WORK

6.1 Summary

Soybean and maize are important crops which are very beneficial for human being. However, productivity of these crops has been decreasing day by day due to monocropping which has led to imbalance in soil fertility. Continuous use of inorganic fertilizer in higher amount has played a vital role in reducing the soil health since the new varieties of the crop require higher amounts of nutrient to increase the yield but this affects the quality of the soil as well as the produce. Although the present demand for organic products is increasing day by day. Several research workers have recommended for supplementing organic nutrients in place of inorganic fertilizers which will help in producing quality crops as well as improving the soil health. Keeping the points in view the present experiment was undertaken with the following objectives-

- To find out the effect of different farming systems on growth and yield of soybean + maize intercropping
- To find out suitable production system for soybean+ maize intercropping
- To work out the economics of different farming systems

A field experiment was conducted at instructional Research Farm, Krishi Nagar, Department of Agronomy, college of Agriculture, JNKVV Jabalpur (M.P.) during *kharif* season of 2022.

The experiment was laid out in randomized block design with four replication and six treatments. The treatment comprised of T₁ (control), T₂ (Natural farming practices (Beejamrit + Ghanjeevamrit + Jeevamrit, Mulching), T₃ (Organic farming practices (FYM@3.5t/ha, VC@1.75t/ha, Neemcake@0.58t/ha), T₄ (50% organic + 50% inorganic NM) with Neemastra and Brahmastra), T₅ (50% organic + 50% inorganic NM with need-based pesticides) and T₆ (100% Inorganic farming practices) in soybean + maize intercropping.

Results

Growth and yield

The growth parameters of maize and soybean i.e., plant height, number of branches, LAI, number of root nodules, dry weight of root nodules and dry matter production were affected significantly due to different nutrient management practices at all the growth stages.

Among different treatments Integrated nutrient management with Brahmastra and Neemastra (INM+BN) recorded highest plant height of soybean (50.08 cm) which was at par with Integrated nutrient management with need-based pesticides (INM+NBP) (48.67cm) followed by Inorganic farming practices (IFP)(46.22cm) and Organic farming practices (OFP)(44.78cm). The minimum plant height was recorded under Control (39.23 cm) at harvest. In case of maize Integrated nutrient management with Brahmastra and Neemastra recorded maximum plant height i.e., 191.03 cm, which was at par with inorganic farming practices (181.18cm) followed by Integrated nutrient management with need-based pesticides (169.88cm).

Branches per plant increased up to 60 DAS. Integrated nutrient management with Brahmastra and Neemastra in soybean showed significantly higher number of branches per plant (6.65) which was at par with Integrated nutrient management with need-based pesticides (6.50) followed by inorganic farming practices (6.10). The lowest number of branches (4.50) per plant was recorded in (control).

The highest leaf area index of soybean (1.9, 4.61 cm² at 30 and 60 DAS respectively) was obtained in INM+BN. It was found at par with INM+NBP (1.7, 4.31cm²) followed by IFP (1.69, 4.12cm²). The minimum LAI (1.43, 3.7cm²) was recorded under control at 30 and 60 DAS respectively. In case of maize highest leaf area index (2.62, 8.13cm² at 30 and 60 DAS respectively) was recorded in INM+BN which was found at par with IFP (2.45, 8.03) followed by INM+NBP (2.37, 7.85). The minimum LAI was recorded under control (2.21, 6.48 cm² at 30 and 60 DAS respectively).

The highest number of root nodules (40.29, 47.99/plant at 30 and 60 DAS respectively) was observed in OFP which was at par with INM+BN

(37.13, 44.69) followed by INM-NBP (37.90, 46.51) and IFP (37.92, 45.86). The highest dry weight of root nodules (0.58 g) was recorded in treatment OFP which was at par with INM+BN but significantly superior over other treatments.

Among the different the treatment of INM+BN produced the highest dry matter in soybean (3.47, 10.90, 35.10 and 32.18g at 30, 60, 90 DAS and at harvest respectively). The lowest dry matter production was observed in control (2.81, 9.29, 26.63 and 27.84g at 30, 60, 90 DAS and at harvest respectively). In case of maize treatment INM+BN gave the highest dry matter production (16.31, 122.31, 235.79 and 255.79g at 30, 60, 90 DAS and harvest respectively). The lowest dry matter production was observed in control (14.84, 102.38, 200.75 and 217.15g at 30, 60, 90 DAS and at harvest respectively).

Different yield attributing traits of soybean like pods per plants and seed index were also influenced significantly by different treatments. The treatment INM+BN produced the highest number of pods (48.66 pods/plant) which was at par with INM+NBP (47.84), IFP (46.18), OFP (45.44) and NFP (44.71). The lowest pods per plant (42.89) were counted under Control.

The number of seeds per pod was not influenced significantly by different treatments.

The maximum test weight (107.87 g) was recorded under INM+BN which were at par with INM+NBP followed by IFP, OFP and NFP. However, it was significantly superior over Control.

The effect of different treatments on yield attributing parameters of maize was recorded and statistically analyzed. The number of cobs per plant was not influenced significantly by different nutrient management treatments.

The treatment Integrated nutrient management with Brahmastra and Neemastra recorded significantly higher (14.25 cm) cob length which was at par with IFP (13.25cm) followed by INM+NBP (13.25cm), OFP (13cm) and NFP (12.08CM). The lowest cob length (11.83 cm) was measured under Control.

The Highest cob girth (13.16 cm) was measured in Integrated nutrient management with Brahmastra and Neemastra (INM+BN), which was at par with IFP (12.91cm) followed by INM+NBP (13cm), OFP (12.67cm) and NFP (12.42cm). The lowest cob girth (11.92 cm) was measured under Control.

Among different nutrient management practices highest cob weight (87.17 g) was measured in INM+BN which was at par with IFP (85.30cm) followed by INM+NBP (83.11cm), OFP (79.48cm) and NFP (75.16cm). However, it proved significantly superior over control. Lowest cob weight (71.15g) was measured under Control.

Seeds per cob was highest (346) in INM+BN. It was found at par with IFP (316.69) followed by INM+NBP (301.6) and OFP (289.94). However, lowest seeds per cob (248.66) was recorded under control. The highest seed index (19.77g) was measured in INM+BN which was at par with IFP (18.81) followed by INM+NBP (18.28). The Lowest seed index (17.03g) was found under Control.

The highest seed yield was observed under INM+BN (1414 kg/ha) which was at par with INM+NBP (1383 kg/ha) followed by IFP (1258 kg/ ha). Similar trend was followed in case of soybean stover, the highest stover was observed in INM+BN (3166 kg/ha) which was at par with INM+NBP (3068 kg/ha). However, significantly lower seed yield 711 kg/ha was recorded under Control. in case of maize, the treatment INM+BN produced significantly higher seed yield (1536 kg/ha) which was at par with IFP (1488kg/ha) followed by INM+NBP (1442 kg/ha). While in case of maize stover, maximum stover was observed under INM+BN (3440 kg/ha) which was at par with IFP (3043 kg/ha) followed by INM+NBP (2962 kg/ha) and OFP (2991 kg/ha). The highest soybean equivalent yield 2114 kg/ha was obtained in INM+BN which was at par with INM+NBP (2041 kg/ha) followed by IFP (1937 kg/ha). The lowest SEY (1221 kg/ha) was obtained under control.

The maximum harvest index higher harvest index of soybean (31.56) was recorded in OFP which was at par with IFP (31.44). The lowest harvest index (29.34) was observed under NFP. In case of maize IFP gave the highest (33.06) harvest index while lowest HI (30.67) was observed in NFP.

Soil properties

It is clear from the results that soil pH slightly reduced all treatments except in IFP in which it was increased as compared to initial status of soil. While in case of EC and OC of soil under different treatments did not find any significant changes but in case of available N, P and K of soil showed significant difference under different treatments with increased values from initial soil status.

Production economics

The lowest cost of cultivation was estimated under control (Rs. 28583). The cost increased in the range of Rs 28583 to Rs. 51571 with the variations in the treatments. However, the highest cost was found in OFP which was Rs. 51571.

Amongst the different treatments the maximum gross return Rs. 102413 was obtained in INM+BN followed by INM+NBP (Rs 97605), IFP (Rs. 92294), OFP (Rs. 86235) and NFP (Rs. 76231). The lowest gross return (Rs. 58806) was obtained under control.

Among different treatments, IFP registered highest net returns (63521 Rs. ha⁻¹) followed by INM+NBP (55306 Rs ha⁻¹), INM+BN (54864 Rs ha⁻¹), NFP (40290 Rs ha⁻¹) and OFP (34664 Rs ha⁻¹). The lowest net returns (30223 Rs. ha⁻¹) was estimated under control.

Among different treatments, IFP gave the highest benefit- cost ratio 3.20. The lowest B:C ratio (1.67) was computed in organic farming practices.

6.2 Conclusion

Integrated nutrient management with Brahmastra and Neemastra proved superior over other practices as it recorded significantly higher growth and yield of soybean as well as maize.

Among different treatments, Integrated nutrient management with Brahmastra and Neemastra appeared to be the most suitable production system for soybean + maize intercropping with the highest Soybean equivalent yield. The values of available nutrients after crop harvest were also higher under the same treatment.

Integrated nutrient management along with Brahmastra and neemasthra fetched highest Gross monetary returns. However, the highest values of net monetary returns as well as B:C ratio was observed under inorganic sources of nutrients closely followed by Integrated nutrient management with need based pesticide and Integrated nutrient management with Brahmastra and Neemastra.

6.3 Suggestions for further work

The study should be further repeated with the same variety and cropping system under the same treatments, since the observations concluded are based on one year trial.

The cost of organic inputs should be scientifically worked out for further consideration in experimental treatments, in order to reduce the cost of cultivation.

Chapter - VII

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BIBLIOGRAPHY

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APPENDICES

APPENDIX - I

Cost of cultivation of soybean + Maize (4:2) Control-T₁

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs., Leveling - 2 hrs.	500 Rs. /hrs	2250
Seed	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Drainage	Channels by furrow openers by tractors driven- 1hrs.	500 Rs. /hrs.	500
Weeding	• Hand hoeing 10 labours • Manual 25 labours	300 Rs. / man	3000+7500 = 10500
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3 hrs.	1000Rs./man	3000
Miscellaneous			1800
Total cost			28583

Fixed cost- Rs. 18083

Variable cost- Rs. 10500

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Cost of cultivation of soybean + Maize (4:2) NFP-T₂

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs, Leveling - 2 hrs.	500 Rs. /hrs.	2250
Seed rate	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Seed treatment	Beejamrit 3 ml/kg seeds (180ml)	Rs.600/lit.	108
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Mulching	6t/ ha after sowing	2 Rs./kg	12000
Drainage	Channels by furrow openers by tractors driven- 1hr.	500 Rs. /ha	500
Manure application	FYM – 250 kg/ha	2 Rs. /kg	500
	Ghanjeevomit - 250 kg/ha	3.5 Rs. /kg	875
	Jeevamrit – 500lit/ha	2.4 Rs./lit	1200
Plant protection	Neemastra 5 lit/ha	140 Rs./lit	700
	Brahmastra 5 lit/ha	140 Rs./lit	700
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3hrs	1000Rs./man	3000
Miscellaneous			1800
Total cost			35941

Fixed cost- Rs. 18083

Variable cost- Rs. 17858

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Cost of cultivation of soybean + Maize (4:2) OFP-T₃

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs., Leveling - 2 hrs.	500 Rs. /hrs	2250
Seed rate	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Seed treatment	Trochoderma 5g/kg. = 300gm Pseudomonas 5g/kg = 300gm	1kg=Rs.200 1kg =Rs.226	60 + 68 = 128
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Drainage	Channels by furrow openers by tractors driven- 1hr.	500 Rs. /ha	500
Manure application:	FYM – 3500kg/ha	2 Rs./kg	7000
	Vermi-compost- 1750 kg/ha	4 Rs./kg	7000
	Neem cake - 580 kg/ha	12 Rs./kg	6960
	Rock phosphate-100kg/ha	5 Rs./kg	500
Weeding	Hand hoeing 10 labours Manual 25 labours	300 Rs. / man	3000+7500 = 10500
Plant protection	Neemastra 5 lit/ha	140 Rs./lit	700
	Brahmastra 5 lit/ha	140 Rs./lit	700
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3hrs	1000Rs./man	3000
Miscellaneous			1800
Total cost			51571

Fixed cost- Rs. 18083

Variable cost- Rs. 33488

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Cost of cultivation of soybean + Maize (4:2) INM+BN-T₄

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs., Leveling - 2 hrs.	500 Rs. /hrs	2250
Seed rate	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Seed treatment	Trochoderma 5g/kg. = 300gm Pseudomonas 5g/kg = 300gm	1kg=Rs.200 1kg =Rs.226	60 + 68 = 128
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Drainage	Channels by furrow openers by tractors driven- 1hr.	500 Rs. /ha	500
Manure application:	FYM – 2330kg/ha	2 Rs./kg	4660
	Vermi-compost- 1160 kg/ha	4 Rs./kg	4640
	Neem cake - 390 kg/ha	12 Rs./kg	4680
	Urea-76 kg/ha SSP-344 kg/ha MOP-30 kg/ha	5.36 Rs/kg 7.3 Rs/kg 18 Rs/kg	407+2511+ 540=3458
Weeding	Hand hoeing 10 labours Manual 25 labours	300 Rs./man	3000+7500 = 10500
Plant protection	Neemastra 5 lit/ha	140 Rs./lit	700
	Brahmastra 5 lit/ha	140 Rs./lit	700
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3hrs	1000Rs./man	3000
Miscellaneous			1800
Total cost			47549

Fixed cost- Rs. 18083

Variable cost- Rs. 29466

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Cost of cultivation of soybean + Maize (4:2) INM+NBP-T₅

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs., Leveling - 2 hrs.	500 Rs. /hrs	2250
Seed rate	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Seed treatment	Trochoderma 5g/kg. = 300gm Pseudomonas 5g/kg = 300gm	1kg=Rs.200 1kg =Rs.226	60 + 68 = 128
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Drainage	Channels by furrow openers by tractors driven- 1 hr.	500Rs. /hrs	500
Manure application:	FYM – 2330kg/ha	2 Rs./kg	4660
	Vermi-compost- 1160 kg/ha	4 Rs./kg	4640
	Neem cake - 390 kg/ha	12 Rs./kg	4680
	Urea-76 kg/ha SSP-344 kg/ha MOP-30 kg/ha	5.36 Rs/kg 7.3 Rs/kg 18 Rs/kg	407+2511+ 540=3458
Weeding	Pendimethlin – 3 ml/lit Two Man labours Hand hoeing 15 labours	400Rs. / lit 300 Rs./man	1200+600=18 00 4500
Plant protection	Chlorpyrifos – 1.5 lit/ha Two man labours	500 Rs./lit 300Rs. / man	750 600
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3hrs	1000Rs./man	3000
Miscellaneous			1800
Total			42299

Fixed cost- Rs. 18083

Variable cost- Rs. 24216

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Cost of cultivation of soybean + Maize (4:2) IFP-T₆

Particulars or inputs	Rate/Quantity	Unit cost	Cost (Rs.)
Field preparation (By tractor)	Cross harrowing – 2.5 hrs., Leveling - 2 hrs.	500 Rs. /hrs	2250
Seed rate	Soybean - 53.33 kg Maize - 6.66 kg	75 Rs. /kg 80 Rs. /kg	4000 + 533 = 4533
Seed treatment	Vitavax 2g/kg seeds 60kg seeds	2000/kg 120 g	240
Sowing	By Tractor 3hrs	500 Rs. /day	1500
Drainage	Channels by furrow openers by tractors driven- 1 hr.	500Rs. /hrs	500
Manure application N:P:K Soybean- 20:60:20, Maize- 80:40:20	Urea 87 kg/ha	5.36 Rs./kg	466 +
	SSP 334 kg/ha	7.3 Rs./kg	2438 +
	MOP 33.11 kg/ha	18 Rs./kg	596 +
	4 Man labours	300Rs. / man	1200 = 4700
Weeding	Imazethapyr 900 ml Spraying cost 4 labours	1500 Rs/lit 300 Rs/man	1350+1200 =2500
Plant protection	Chlorpyriphos 3 lit/ha Spraying labour- 4	700 Rs/lit. 300 Rs/man	2100 + 1200 = 3300
Harvesting	Manually 15 Man-days	300Rs./man	4500
Threshing	By thresher 3hrs	1000Rs./man	3000
Miscellaneous			1800
Total			28773

Fixed cost- Rs. 18083

Variable cost- Rs. 10690

Market price – soybean (Rs. 43/kg) and maize (Rs. 19.62)

Stover sale price- soybean (Rs. 2/kg) and maize (Rs. 1.50/kg)

Source	D.F	Plant Population		Plant Height (cm)				Branches Per Plant			Root Nodules/ Plant		Dry Weight of Nodules		LAI		Dry Matter Production (g)			
		20 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	Harvest
Treatments	5	2.17	3.41	15.90	56.10	58.11	60.80	1.45	2.92	3.56	24.24	45.77	0.01	0.02	0.09	0.44	0.21	1.50	10.12	9.86
Replication	3	4.74	3.48	9.51	53.95	41.09	45.92	0.51	0.05	0.06	2.64	26.98	0.01	0.00	0.10	0.29	0.01	0.99	2.87	2.23
Error	15	4.38	2.36	10.09	16.15	16.55	18.15	0.26	0.41	0.41	8.42	23.83	0.00	0.00	0.06	0.12	0.06	0.43	3.35	3.38

Source	D.F	Pods/plant	Seeds/pod	Test Weight(g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Soybean equivalent yield (kg/ha)
Treatments	5	17.71	0.07	68.92	281067.74	1547297.59	5.65	451317.98
Replication	3	20.28	0.03	1.26	36322.34	205299.44	0.06	48038.18
Error	15	13.87	0.03	26.83	14032.07	71205.48	0.09	23425.83

Source	D.F	Plant Population		Plant height (CM)				LAI		Dry matter production (g)			
		20 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	Harvest
Treatments	5	1.21	1.25	54.61	213.31	842.44	837.04	0.08	1.66	1.10	195.09	676.13	791.44
Replication	3	1.31	1.18	9.51	118.15	492.87	496.74	0.01	0.22	2.69	145.54	411.75	411.75
Error	15	1.97	2.14	16.97	97.81	286.63	287.44	0.03	0.13	1.24	67.26	237.57	237.57

Source	D.F	Cobs/plant	Cob length	Cob girth	Cob weight	No of seeds/ cob	Seed index	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Treatments	5	0.23	3.10	110.01	4560.92	4892.09	3.91	102682.81	574174.51	3.20
Replication	3	0.04	2.69	0.72	94.34	1883.34	0.22	14918.55	100307.07	0.02
Error	15	0.10	2.23	0.42	93.31	1606.80	2.32	13647.13	113919.51	0.06

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Educational qualification

Name of the Degree	Subjects (Major)	Name of the Institution	Year of passing
M.Sc. (Agriculture)	Agronomy	J.N.K.V.V, Jabalpur, (MP)	2023
B.Sc. (Ag.) Hons.	Agriculture	J.N.K.V.V, Jabalpur, (M.P.)	2021
12 th	Science	Govt. H. S. Excellence School No.1, Tikamgarh, (M.P.)	2015
10 th	Math's, Science, Social science, English, Hindi	Maharishi Vidya Mandir Tikamgarh (M.P.)	2013

For the fulfilment of the master's degree programme, he was allotted a research problem **“Studies on the performance Soybean + Maize intercropping under different farming systems”**. This is duly completed by her and presented in the form of this thesis.