EFFECT OF INTEGRATED INPUT MANAGEMENT ON NUTRIENT BALANCE UNDER SOYBEAN BASED CROPPING SYSTEM

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

By
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DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled **"EFFECT OF INTEGRATED INPUT MANAGEMENT ON NUTRIENT BALANCE UNDER SOYBEAN BASED CROPPING SYSTEM"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place : Nagpur

Date : 31/05/2010

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CERTIFICATE

This is to certify that thesis entitled **"EFFECT OF INTEGRATED INPUT MANAGEMENT ON NUTRIENT BALANCE UNDER SOYBEAN BASED CROPPING SYSTEM"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Agriculture (Soil Science and Agricultural Chemistry)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by KUCHANKAR HUMADEVI WAMANRAO under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place : Nagpur

Date: 31/05/2010

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Associate Dean,
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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE
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Abbreviations

@	at the rate
a.i.	Active ingredient
CD	Critical difference
DAS	Days after sowing
dSm^{-1}	desicimens per meter
ETL	Economic threshold level
Fig.	Figure
FYM	Farm yard manure
MWD	Mean wet diameter
NS	Non significant
PE	Pre emergence
PPI	Plant protection incorporation
PSB	Phosphate solubilizing bacteria
RDF	Recommended dose of fertilizers
SE ± (m)	Standard error of mean
Sig.	Significant
SSP	Single super phosphate

THESIS ABSTRACT

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ABSTRACT

The field investigation relating to "Effect of Integrated Input Management on Nutrient Balance under soybean based cropping system." was undertaken during Kharif and Rabi season of 2009-10 at EAD from college of Agriculture, Nagpur.

The experiment was laid out in strip plot design with there modules replicated four times. Treatment consisting of 5 t FYM (organic module), 100% RDF (inorganic module), 50% RDF + 5t FYM (Integrated module). The soil of experimental site was clayey, alkaline in soil reaction, moderately high in organic carbon, medium in available nitrogen, moderately high in available phosphorous and very high in available potassium, low in available sulphur medium in exchangeable Ca and Mg and DTPA extractable micronutrients Fe and Zn is low whereas Mn and Cu is found sufficient. The plant sample of soybean, wheat and gram were collected at harvest and further processed and were analyzed for different chemical parameters as per standard procedure.

Soil pH, electrical conductivity, organic carbon were improved with the application of organic fertilizers alone (organic module) or in combination with inorganic fertilizers (integrated modules) than inorganic modules. Available N, P, K, S and exchangeable Ca and Mg DTPA extractable Fe, Mn, Zn and Cu is highest with application of 50% RDF + FYM @ 5 t ha^{-1} (integrated modules) after harvest of soybean, wheat and gram.

Results revealed that highest grain and straw yield of soybean were obtained with 50 % RDF + FYM @ 5 t ha^{-1} whereas wheat equivalent grain yield and straw yield were obtained higher in 100% RDF followed by 50% RDF + FYM @ 5 t ha^{-1}.

Uptake of N, P, K, S, Fe, Mn, Zn and Cu was found significantly higher in an integrated module (50% RDF + FYM @ 5 t ha^{-1}) at harvest of soybean

crop. Uptake of N, S, Fe, Mn, Zn and Cu was found significantly higher in integrated module whereas uptake of P and K was found significantly higher in an inorganic module (100% RDF) Application of 50% RDF with organic manure significantly influence the soil properties and yield under both cropping systems and input management modules.

Legumes either soybean or gram removed higher quantity of nitrogen, phosphorous and potassium at harvest of soybean and at harvest of wheat and gram maximum amount of nitrogen is removed in soybean-gram cropping sequence, whereas phosphorous and potassium is removed in soybean-wheat cropping sequence.

Chapter I

INTRODUCTION

1.1 Background information

Integrated nutrient management is emerging as the most logical concept for managing long term soil fertility and productivity. Integrated use of organic manures and chemical fertilizers has been found to be promising in arresting the decline in productivity through the correction of marginal deficiencies of some secondary and micronutrient elements and its beneficial influence on the physical, chemical and biological properties of the soil. Integrated nutrient management system can bring about equilibrium between degenerative and restorative activities in the soil environment (Kumar *et al.* 2007).

In the modern era of agriculture several new concepts like partial nutrient management, comprehensive nutrient management, site specific nutrient management are cropping up which are beneficial for crop, soil and environment as well. Due to vertical and horizontal intensification of agriculture, which has led to huge nutrient mining even from the high fertile soils, a wide gap has been created between nutrient addition and removal in the soil. Till we reach the ultimate goal of optimum soil, food and environmental quality through organics, a judicious combination of inorganic and organic sources is desirable. For partial substitution of inorganic fertilizers important practices like crop residue management, organic matter enrichment through organic waste recycling, agro-industrial waste utilization etc. are beneficial. Along with this, a paradigm shift in the faulty agricultural practices can be of great help like adoption of suitable cropping systems and crop rotations, green manuring, mulching which reduce soil erosion and maintain optimum soil health on a sustainable basis (Rathore and Rathore, 2006).

The nature and behaviour in soil of the essential and beneficial plant nutrients like iron, manganese, copper, zinc, traditionally called as micronutrients needed by plants in small amounts and their reserves are limited. These can be depleted due to continuous cropping, erosion and leaching and with the use of high nitrogenous and phosphatic fertilizers in the intensive cropping system with less use of organic manures. Micronutrient deficiencies are widespread, 50% of world cereal soils are deficient in zinc and 30% of cultivated soils globally are deficient in iron. These are the most severe deficiencies. Moreover, steady growth of crop yield during recent decades (in particular through the green revolution) actually compounded the problem by progressively depleting soil micronutrient pool. This trend will continue unless appropriate steps are taken. In many places, the supply of micronutrients to crop is low compared to their uptake. Therefore it is imperative to look at micronutrient balance urgently. Thus balanced fertilization implies movement in the supply of nutrients while maintaining or improving the fertility of the soil without any harmful effects on the environment, through the use of all essential secondary and micronutrients in addition to NPK to obtain higher yields.

To sustain the productivity of different cereal crops and cropping system, efficient nutrient management is vital. There is a need to develop more efficient, economic and integrated system of nutrient management for realizing high crop productivity without diminishing soil fertility while fertilizer use is a must for higher crop production, imbalanced use should be avoided in order to get better results. Increasing the cropping intensity as well as production per unit area per unit time is now gaining ground for improved production (Randhawa, 1986, Kanwar and Sekhon, 1998).

Soybean (Glycin Max L. Merril) offers good potential in cropping sequence being a short duration legume energy rich oilseed crop next to groundnut and mustard. In Maharashtra area under soybean accounting 2651 thousand hectare with production of 3924 thousand tones (Anonymous, 2007). In Maharashtra area under wheat is 8.50 lakh hectares with the production of 11.91 lakh tonnes where as in Vidarbha region area under wheat is 2279 ha with the production of 3463 tonnes (Anonymous 2006) Gram which is popularly called as Chickpea or Bengal gram is the most important pulse crop of India which has 75% world average and production occupies about 31%. It has high nutritive with 21.1% protein, 61.5% carbohydrates, 45% fat and good amount of calcium, iron and niacin.

Soybean in India and Maharashtra is continuously increasing due to dual utility as pulse as well as seed crop besides it has better market price, it has high protein content (40 - 42%) and oil content (20 - 22%). It is grown under rainfall from 800 - 1200 mm almost all type of soil. Soybean crop contribute 24 - 30% ha^{-1} residues which can be recycled and nutrient content there in be hamassed for the succeeding crop besides improving the soil fertility. Among the plant parts, nitrogen contents of roots (1.81% N), root of soybean is quite high in P_2O_5 content (1.16%) whereas potash content in the root, stem and the leaves of soybean appeared rich source (1.52 - 1.89%).

Food grain production per kg of nutrients applied is declining. Probably due to imbalanced fertilizer use and deficiency of secondary and micronutrient, fertilizer input is also becoming costlier. Under such situation, nutrient input management under soybean based cropping system is very important option. Addition of crop residues into the soil is important practice for achieving sustainability in agricultural production and fertility status of soil. Awareness of environment aspect of soil quality, and crop production has been increasing in recent years. This has lead to the renewed interest in crop residues and other organic manures as source of soil organic matter and nutrients. For crop residues management practices influences agricultural sustainability by altering the organic matter status of physical and chemical properties of soils which all interact for better microbial activity and diversity.

1.2 Importance of study

Organic manures like farm yard manure (FYM) and compost; biofertilizers are an adventitious source of several nutrients, and have been traditionally important input for maintaining soil fertility and ensuring yield stability. FYM and vermicompost are helpful to recoup the soil health. Use of vermicompost in addition to improving soil health also imparts pest tolerance to the plants. Composting is one successful method of inactivation of pathogen and decomposing crop residues more rapidly. Composted crop residues reduced the incidence of diseases as well as increased the seed yield of rainfed legume. With the continuous application of organic manure, Zn and S deficiency can successfully be corrected. Apparently complimentary and supplementary role of organic manures is a practicable and profitable strategy. Maintenance and improvement in soil quality through increased organic matter contents and reduced erosion rates are goals that are being widely embraced by growers and environmental protection groups. Sustainability, considering both economic and environmental terms, is best addressed through improving soil quality in agro - ecology. (Rathore and Rathore 2006). Even though so called balanced use of chemical fertilizer will not be able to sustain high productivity due to emergence of deficiency of one or more secondary and micronutrients.

Integrated nutrient management system may also help to check the emerging deficiency of nutrients other than N, P and K and favourably affects chemical environment of soil. In the context of search for alternate source of soil fertility build up through renewable source of soil fertility build up through renewable sources harnessing of bacteria and other micro organisms for fixing N efficient utilization of P assumes great importance. Microorganisms fix about 139 million tonner of N every year (Venkatraman, 1998). It is therefore possible to meet a large part of the total N demand through proper husbandry of micro-organisms in crop production system.

Various studies have proved the importance of bio-fertilizers in agriculture. Bio-fertilizers cost effective, eco-friendly and renewable source of plant nutrient to supplement chemical fertilizer in sustainable agricultural system. Bio-fertilizers have an important role in improving the nutrient supply and their availability for crop production. They help in increasing the biologically fixed atmospheric N and enhancing native P availability to crop. Rhizobium is a potential bio-fertilizer for soybean, which saves about 25 - 50% of recommended dose of nitrogen and enrich soil with nitrogen for succeeding crop (Singh *et al.* 2006). Rhizobium legume association can fix upto 100 - 300 kg N ha^{-1} in one crop season and in certain situation leave substantial N for the following crop (Venkatraman, 1998). Inoculation with efficient rhizobium strain specific to each crop is very essential for the N grains and better crop yield their symbiosis can meet more than 80% of N needs of legume crop. About 10 - 15 percent increase in yield of pulse can be obtained in most of cases as observed in various trials conducted under AICARP (Anonymous, 1995). Azotobacters have ability to fix atmospheric 'N' which in turn increases 'N' supply to the crop. Azotobacter can explain beneficial effect of bacteria on germination of seed.

Seed inoculation with composite inoculant of phosphate solubilising microorganisms alone or with phosphatic fertilizers was found to be more effective. Thus could save 13.2 kg P ha^{-1}. A composite inoculants of *pseudomonas striata* was found to be equally effective to superphosphate @26.4 kg P ha^{-1}. Use of phosphate solubilising bacteria may help in solubilising insoluble 'P' and related rhizobial activity which in turn may increase legume yield.

Cropping system based approach to agro-technology development has gained momentum during the past decade after realization that higher productivity achieved through new-technology could be sustained only by adopting the system based holistic approach. Crop rotation is one of the important factors of sustainable farming system as it serves as a component of integrated nutrient management, for sustaining the productivity of the system through efficient nutrient cycling. Therefore balanced fertilization must be based on the concept of the cropping system as a whole. (Singh *et al.* 2006).

Micronutrients plays an active role in the plant metabolism process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, and hormone synthesis. Micronutrient requirement of crop are relatively small and ranges between their deficiency symptoms and toxicities in plant and soil are rather narrow. The decreased amount of micronutrients in soil and their uptake by plant to such critical level which shows their deficiencies symptoms to different micronutrient treatment, also gave comparatively higher yield than control measures.

1.3 Objective of study

The study was undertaken with the following objectives.

i) To study the effect of organic, inorganic and integrated input modules on changes in fertility status at the end of 5^{th} cycle under soybean based cropping system.

ii) To study the effect of organic, inorganic and integrated input modules on uptake of nutrients in soybean, wheat and gram, and

iii) To work out the balance sheet of nutrients.

1.4 Hypothesis

Conceptually, balanced fertilization would essentially mean rational use of fertilizers and organic manures for supply of nutrients for agricultural production in such manner that would ensure enhanced efficiency of fertilizer use, least adverse effect on environment by minimizing nutrient losses, maintaining soil productivity and sustaining high yield. Balanced fertilization must be based on the concept of integrated nutrient management for a cropping system as this is the only viable strategy advocating accelerated and enhanced use of fertilizer with matching adoption of organic manures and fertilizers so that productivity is maintained for a sustainable agriculture. The balanced nutrition could be achieved through application of multi-nutrient in balanced proportion from fertilizer, organic sources, biological sources, and accurately and precisely through integrated nutrient management on cropping system basis. Indiscriminate or continuous use of chemical fertilizer alone over a long period may cause imbalance in microflora and directly affected the biological properties of soil.

1.5 Scope and Limitation

Large inputs of plant nutrients are needed in multiple cropping systems to attain high productivity and sustain it over long periods. Organic manures can't alone meet the heavy demands of nutrients because of their limited quality and restricted nutrient availability. A complementary use of organic manures and mineral fertilizers may meet the goal of adequate and balanced supply of required N, P, K, S and micronutrients to crops (Kalwe and Rani, 2005).

Integrated use of inorganic and organic sources along with bio-fertilizer not only gives higher yield but also enhances the oil content and protein quality of the grains. The application of inorganic fertilizer along with bio-fertilizer gives better results. The application of rhizobium nitrogen fixation and phosphate solubilizing bacteria (PSB) for availability is most advantageous.

The improved production technology has increased the crop productivity of soybean during last 10 years. Now there is a scope to increase the soil and crop productivity with the judicious use of organic, inorganic and integrated approaches under soybean based cropping system with these views the present investigation aims to study the effect of various modules on crop productivity, uptake of nutrients and soil quality based on soybean wheat and soybean-gram cropping system.

Lack of sufficient awareness among farmers about the negative effects of intensive farming using high analysis fertilizers without concern to conserve the natural resources or soil fertility has also led to mining of soil nutrients which has caused the deficiency over the years. In view of this, there is need of alternative practices of managing the nutrients more judiciously, efficiently and in balanced proportion. Continuous use of FYM or other organic sources arrest the depletion of available micronutrient pool from soil. Development of integrated micronutrient technology using available organic materials in needed not only to increase micronutrient use efficiency but also to decrease the pressure of the use of costly inorganic micronutrient carries.

Chapter II
REVIEW OF LITERATURE

The present investigation was carried out to explore the "Effect of integrated input management on nutrient balance under soybean based cropping system." The relevant literature available in relation to the effect of organic, inorganic and biofertilizer on chemical properties, crop productivity and nutrient uptake of soybean, wheat and gram have been presented and reviewed under suitable heading.

Effect of Integrated input management on

2.1 Chemical properties of soil

2.2 Availability of major nutrients.

2.3 Availability of micronutrients.

2.4 Grain and straw yield of soybean, wheat and gram.

2.5 Concentration and uptake of major nutrients.

2.6 Balance sheet of nutrients

2.1 Chemical Properties of Soil

Singh *et al.* (1980) studied on effect of continuous application of farmyard manure and chemical fertilizer on some soil properties. Results revealed that there is significant increase in cation exchange capacity, organic carbon and available nitrogen, phosphorous and potash content of the soil. There is decrease in pH of soil by about 1 unit from the initial value could be related to the decomposition and mineralization of organic matter.

Sharma *et al.* (1986) studied on residual effect of leguminous crops on some chemical properties of soil and reported that, organic carbon content of soil increased slightly due to cultivation of leguminous crops (0.41%) as compared with soil under the cereals (0.88%) and fallow (0.36%).

He revealed that cultivation of leguminous crop increased total Nitrogen content i. e. 0.07% compared to cereals. (0.05%).

Malewar and Hasnabade (1995) studied on effects of Long- term application of Fertilizers and organic sources on chemical properties of soil and reported that there was increase in organic carbon content (0.97%), considerably there was increase in available nitrogen (165 kg ha^{-1}), available phosphorous (43 kg ha^{-1}), available potassium (417 kg ha^{-1}) in the treatment which has received combined and long term use of organic manures and fertilizers after harvest of wheat crop. It is perhaps due to addition of farm yard manure which stimulates the growth activity of microorganisms. Increase in availability of nitrogen is particularly with farm yard manure or subabul and NPK treated plots which mainly ascribed to bulk of organic residues and higher N content in subabul leaves. Availability of phosphorous which is largely attributed to minimization of P fixation and organic recycling. Higher availability of potassium may be attributed to acidulation as a result of decomposition of organic matter and release of mineral K_2O in soil solution.

Kumar and Prasad (1999) studied on soil fertility and yield as influenced by different legume-wheat sequence and reported that, organic carbon content was increased from (0.44% - 0.49%) after harvest of soybean and it was decreased after harvest of wheat (0.38% - 0.40%).

Babhulkar *et al.* (2000) studied on residual effect of long term application of FYM and fertilizers on soil properties and reported that, the content of organic carbon(6.2 g kg^{-1}) total nitrogen (0.56%), available phosphorus (21.21 kg ha^{-1}) and available potassium (390 kg ha^{-1}) were higher in treatment receiving 15:30 NP + 7.5 t FYM ha^{-1}after harvest of soybean crop. It is perhaps due to addition of FYM which help to stimulate the growth activity of micro organisms .This effect is further enhanced by addition of N and P resulting in the improvement in root and shoot growth.

Higher production of biomass might have increased the organic carbon content. Amongst the cropping sequence soybean followed by gram was superior sequence with respect to organic carbon (5.5 g kg^{-1}) available phosphorus (17.81 kg ha^{-1}) and available potassium (355 kg ha^{-1}).

Jain *et al.* (2005) studied soil properties and maximization of productivity of soybean - wheat system in hill zone of Madhya Pradesh based on three year data, they further reported that, the application of FYM @ 10 tonnes ha^{-1} to soybean improved the organic carbon and N content of soil (285 kg ha^{-1}) and also reported that the soil properties viz. soil pH, organic carbon and N, P, K contents did not deviate much from their initial status due varying rates of fertilizer application.

Singh *et al.* (2006) studied on Integrated plant Nutrient supply for sustainable production in soybean based cropping system and reported that organic carbon content has been increased (0.46-0.56%) in those treatments that had received the combined used of organic and inorganic sources after the harvest of soybean crop.

Ganeshamurthy *et al.* (2006) reported that pulses add significant amount of organic residues to soil in the form of root biomass and leaf litter and have observed that organic carbon content of soil increased over the initial level in all the pulse based cropping system however pulse crops have the ability to reduce the pH of the soil in the rhizosphere and make the micro-environment favourable for nutrient availability. It is well documented that pulses leave substantial amounts of N in the soil after their harvest. An improvement in the N budgets of soils measured by improved soil reserves of readily mineralisable organic N and microbial biomass C and N was found (14 Kg N ha^{-1}) soil NO_3 after chickpea and (28 to 38 Kg N ha^{-1}) after peas than after wheat to a depth of 60 to 120 cm. Further pulses have been found to utilize the applied and residual phosphorous more efficiently and also have the ability to increase availability of P to succeeding crops. They found a net negative balance for N and K and a net positive balance for P.

Kumar *et al.* (2007) reported higher reduction in pH, EC and ESP was observed by using organic manures (FYM, Sesbania GM) along with moderate levels (50-75%) of chemical fertilizers as compared to 100% chemical fertilizers alone. The combined use of mineral fertilizers and organic N sources (50:50) further increased the organic carbon levels to 0.62, 0.54 and 0.59 percent in FYM, Wheat cut straw and Sesbania GM, respectively. The application of 100% NPK through chemical fertilisers or their combined use with organic N sources showed an increase of 10-27 Kg ha^{-1} in available N and 10.4-14.4 kg ha^{-1} in available P status of the soil. This might be due to mineralisation of the organic sources or through solubilisation of nutrients from the native source during the process of decomposition of organic sources. Available K content decreased over the respective initial values in twenty years of continuous rice-wheat cropping.

Shivakumar and Ahlawat (2008) studied on Integrated nutrient management in soybean-wheat cropping system and reported that there was some degree of variation in the organic carbon content, with the initial status in the soil after 3 years of soybean-wheat cropping system. All the treatments improved the organic carbon content over the years. Among the treatments, the combined application of 5 t ha^{-1} each of crop residues and FYM recorded significantly higher organic carbon content in the soil after completion of soybean wheat system compared with 5 t ha^{-1} crop residues and the control among the nutrient sources.

Verma and Mathur (2009) revealed that application of FYM alone or in combination with chemical fertilizers increased soil organic carbon content after harvest of wheat crop. Reasons attributed is the direct incorporation of organic matter, better root growth and more plant residues addition after harvest of crops. Further the organic carbon content of the soil also increased significantly with the application of 100% NPK, 100% NPK + Zn+S, 100% NPK + Azotobacter and 150% NPK treatments. This shows that use of fertilizers alone also helps in increasing organic carbon content of the soil.

2.2 Availability of Major Nutrients

Singh *et al.* (1980) studied on effect of continuous application of farmyard manure and chemical fertilizers on some soil nutrients. Results indicated that, the application of farmyard manure increased significantly the soil properties viz. available nitrogen, phosphorus and potash content of the soil. Phosphate application enhanced the levels of available phosphorus, P fertilizer caused increased in available phosphate in soil. Application of potassium did not results in any significant change in the soil, which might be due high initial potash status of soil.

Sharma *et al.* (1986) studied on residual effect of leguminous crops on some chemical properties of soil. He reported that available nitrogen content of the soil increased after rabi and kharif legumes as compared with those under their respective cereals crops. The lowest values were recorded in fallow soils as expected cultivation of leguminous crops improved available nitrogen status of soil. There was not much difference in the total P content of the soil as affected by the different crops. The soil under the legumes in both rabi and kharif seasons showed more available P as compared with those under the corresponding cereals crops. The increase in available P due to legume cultivation might be described to the development of P solubilizing organisms in the root zone of legumes.

Singh *et al.* (1998) studied on effect of seed inoculation and FYM on biological N Fixation in soybean and nitrogen balance under soybean - wheat system on vertisol. Results indicated that, both FYM application and Rhizobium inoculation to soybean seed increased the available N in soil throughout the crop growth period. The accumulation of larger quantities of available N under FYM inoculated treatment may be due to release of higher amounts of nitrogenous compounds by root nodules at early stages of growth and their subsequent decomposition at later stages. Increase in N accumulation in the later stages may probably due to decline in demand of sink (pods) for N and its subsequent addition to the soil after decomposition of nodules and roots .Among the three treatments FYM recorded highest N accumulation (50 kg ha^{-1}) followed by inoculation (46 N kg ha^{-1}).

Santhy *et al.* (1998) studied on long term effect of continuous fertilization on crop yield and soil fertility status. The long term results indicated that the available N content of the soil increased over the initial values under 100% NPK + FYM treatment which was due to higher organic carbon content. The favourable soil conditions under FYM addition might have helped in the mineralization of soil N leading to build up of higher available N and build up of higher available P status of soil over the initial value recorded in 100% NPK + FYM and also 150% NPK treatment. The FYM being a direct source of P might have also solublized the native P in the soil through release of various organic acids.

Kumar and Prasad (1999) studied on soil fertility and yield as influenced by different legume – wheat sequences. Results based on two seasons found that the available N, P and K in other legume Black gram - wheat sequence, Cowpea-wheat sequence, stylo-wheat sequence plots were also higher as compared with rice-wheat sequence. N added by legumes was utilized by succeeding wheat resulting in reduced available N status of soil after harvest of wheat. In various sequence, a general reduction in available soil P was noticed after the harvest of legumes and wheat. This might be due to higher rate of P fixation in soil .A less quantity of K application to kharif legumes and its losses under high rainfall conditions might be the reasons for low soil K status after harvest of legumes. Generally N levels increased the biomass production and incorporation of organic matter in forms of leaves, roots which led to increased in organic matter and N status of soil.

Kanwar and Paliyal (2002) studied on influence of phosphorus management and organic manuring on uptake and yield of chickpea and reported that there is increasing of available P status of soil with increasing doses of P_2O_5 with or without organic manure in both the years. but significant increase in available P status was found with P application along with organic manures as compared to the fertilizer P application without organic manures. FYM and vermicompost were equally effective in increasing the available P status of soil.

Chitale *et al.* (2003) studied on influence of cereal-legume, legume - cereal and cereal - cereal sequences on productivity economics and soil fertility status. Results indicated that after completion of two crop cycles. Available N and P but not K status of the soil was significantly affected due to different treatments. Improvement in available N and P status was noted due to increase in fertilizer rate from 75 to 100% of RDF. Legume crop including green manuring provided considerable amount of residual N to the forthcoming cereal crops. Soybean and green manuring added rice at the end of Kharif season and chickpea only with 100% RDF at the end of rabi season left significant amount of nitrogen over cereal crops of the respective season. The inclusion of available P status of the soil due to mobilization of phosphorus from the sub soil to the upper region.

Jain and Singh (2003) reported that, inoculation with rhizobium + PSB significantly increased the availability of N in soil after harvest of the crop and the corresponding increase was 13.61% over control. But application of phosphorus did not improve the status of available N in soil. Inoculation with rhizobium + PSB and graded application of phosphorus significantly increased the availability of P in soil at harvest. The extent of increase in P was 13.57% and 24.52% respectively, over control. Seed inoculation with biofertilizer resulted in greater P availability due to solubilization of native P by PSB.

Chaturvedi and Chandel (2005) studied on influence of organic and inorganic fertilization on soil fertility and productivity of soybean and reported that, use of organic sources helped in maintaining soil fertility in terms of available nutrients. The higher nitrogen, phosphorus and potassium were recorded with the application of recommended dose of NPK with FYM @ 10 t ha^{-1} showing 10.3, 24.0 and 4.3% increased over the control respectively. Integrated nutrient management significantly increased the available nitrogen and phosphorus in soil compared to initial values where as in the control plots they declined significantly.

Ganeshamurthy *et al.* (2006) reported that the availability of nutrients in the field crop with pulses increases after their harvest and further pulses have been found to utilise the applied and residual phosphorous more efficiently and also have the ability to increase the availability of P to succeeding crops. They found a net negative balance for N and K and a net positive balance for P. It is well documented that pulses leave substantial amounts of N in the soil after their harvest. An improvement in the N budget of soils measured by improved soil resources of readily mineralisable organic N was found 14 kg N ha^{-1} soil NO_3 after chickpea.

Kumar *et al.* (2007) reported that the application of 100% NPK through chemical fertilizers or their combined use with organic N sources showed an increase of 10-27 kg ha^{-1} in available N and 10.4-14.4 kg ha^{-1} in available P status of the soil while available K content decreased over the respective initial values in twenty years of continuous rice - wheat cropping. They also concluded that further among different organic sources of N applied through FYM and sesbania green manuring registered more increase in available N and P content of the soil than 100% NPK through fertilizers alone. The build up in available N and P status of the soil by applying fertilizers and organic N sources is attributed to the residual effect of applied fertilizers and to the mineralization of organic sources or through solubilisation of nutrients from the native source during the process of decomposition of organic sources.

Shivakumar and Ahlawat (2008) studied on Integrated nutrient managment in soybean wheat cropping system and reported that there was some degree of variation in the available N,P,K with the initial status in the soil after 3 years of soybean wheat cropping system. Combined application of 5 t ha^{-1} each of crop residues, FYM recorded significantly higher available N and P in the soil after completion of soybean wheat system compared with 5 t ha^{-1}crop residues and the control among the nutrient sources. It also recorded significantly higher available K after soybean-wheat cropping system. Similarly, 100% RDF to soybean recorded significantly higher available N and P in the soil as compared with 50% RDF and the control. Available status of P and K in the soil increased due to the integration of organic and inorganic sources.

Verma and Mathur (2009) studied on effect of Integrated Nutrient Management on active pools of soil organic matter under Maize - wheat system and reported that maximum soil microbial biomass nitrogen was found in treatment receiving 100% NPK + 10 t FYM ha^{-1} followed by 10 t FYM ha^{-1} + (100% NPK-NPK content of FYM) and 20 t FYM ha^{-1}. At the harvest of both crops, biomass nitrogen varied from 20.2 (Control) to 43.2 mg kg^{-1} (maize harvest) and from 23.2 (control) to 41.2 mg kg^{-1} (wheat harvest). Application of FYM in combination with inorganic fertilizers resulted in significantly higher soil microbial biomass nitrogen, soil microbial biomass phosphorous recorded after the harvest of maize and wheat was 2.99 and 3.08 mg kg^{-1}, respectively under control and it is increased to 5.99 mg kg^{-1} on maize and 6.18 mg kg^{-1} on wheat harvest in the treatments receiving 150% NPK. Integrated use of organics and inorganics significantly increased the crop productivity and provided substrates essential for microbial growth and activity which in turn was responsible for this increase in soil microbial biomass phosphorous.

2.3 Availability of Micronutients

Malewar and Hasnabade (1995) studied on effects of long term application of fertilizers and organic sources on some properties of vertisol and reported that DTPA-Zn build up was improved nearly two times over control in combined application of organic and inorganic treatment and it was (1.13-1.52 mg kg^{-1}) which may be justified on the basis of formation of metalo-organic complexes of higher extractability due to availability of COOH from humic substances and zinc metal in soil. Perhaps these observations lead to conclude that use of FYM, green manure or subabul leaves to the extent of 50% recommended N with 50% through NPK fertilizers is a judicious blend to maintain soil fertility for sustainable soil productivity.

Babhulkar *et al.* (2000) studied on residual effect of long term application of FYM and fertilizers on soil properties and reported that the available sulphur (15.54 mg kg^{-1}) and available zinc (1.46 mg kg^{-1}) has been found to be increased in the treatment that has received full doses of NP fertilizers along with 10 kg $ZnSO_4$ ha^{-1}. This indicates that the application of zinc fertilizers combination with NP fertilizer increases the availability of zinc and sulphur.

Kumar *et al.* (2007) reported that DTPA extractable Zn (0.93 $mgkg^{-1}$), Cu (1.03 $mgkg^{-1}$), Mn (9.2 $mgkg^{-1}$) and Fe (23.4 $mgkg^{-1}$) has been raised in the treatment that has received 50% NPK + 50%N (GM) after completion of 18 cycles of rice-wheat system. It has been concluded that the rate of depletion was more in 100% chemical fertilizer treated plots as compared to their combined use with organic N sources. Chelating actions of organic compounds released during decomposition of organic measures increased the availability of micronutrient cations and also presented their fixation, precipitation, oxidation and leaching.

Shivakumar and Ahlawat (2008) studied on integrated nutrient management in soybean-wheat cropping system reported that there was some degree of variation in the DTPA-extractable zn compared with the initial status in the soil after 3 years of soybean-wheat cropping system. Among the treatments the combined application of 5 t ha^{-1} each of crop residues, FYM and 5 kg ha^{-1} zinc recorded significantly higher available zn (0.56 mg kg^{-1}) in the soil after completion of soybean-wheat system compared with 5 t ha^{-1} crop residues and the control among the nutrient sources. Both 50% and 100% RDF to soybean recorded significantly higher available zn in the soil as compared with the control.

2.4 Grain and straw yield of soybean, wheat and gram

Singh *et al.* (1983) reported that, legumes crop grown significantly increases grain and straw yield of subsequent wheat compared to cultivated fallow and sorghum fodder. Highest yields of wheat grain (47.6 q ha^{-1}) and straw (85.7 q ha^{-1}) were obtained when 120 kg N ha^{-1} was applied after the fertilized grain cowpea followed by fertilized green gram. Wheat after fertilized grain cowpea without nitrogen produced about 2.6 and 2.2 times more grain and straw. Cowpea which continued to grow and added more organic matter. It brings out that kharif legumes were beneficial to succeeding wheat.

Sharma and Bajpai (1989) revealed that the Kharif legumes significantly increased the grain and straw yield of succeeding wheat crop. The main effect of nitrogen application showed significant increase in grain and straw yield of wheat up to level of 120 kg N ha^{-1}. In the first year it was found to be 46.5 q ha^{-1} as against 37.6 q ha^{-1} at no nitrogen level. Similarly, the straw yield at 120 kg N ha^{-1} was recorded as 84.5 and 83.6 q ha^{-1} against at 0 level of nitrogen during the year 1978 - 79 and 1979 – 80, respectively. The residual response of kharif legume irrespective of N level was significant with regard to grain and straw yield of succeeding wheat crop.

Gangwar *et al.* (1992) studied the integrated nutrient management in fodder sorghum - gram cropping sequence under dryland conditions and reported that significantly higher grain yield of gram was obtained with 100% recommended inorganic fertilizer followed by 50% of inorganic fertilizer combined with 6 tonnes farmyard manure ha^{-1}. The higher grain yield under these treatments might be due to higher values of yield attributed such as plant height, branches / plant, pods / plant and 1000 grain weight. The increase in the grain yield of gram was 15.14 q ha^{-1} with 100% inorganic fertilizer, compared with the control 7.57 q ha^{-1} produced significantly higher green fodder yield 276-365 q ha^{-1} of sorghum and grain yield (15.14 -18.13 q ha^{-1}) of gram. Application of 6 tonnes farmyard manure ha^{-1} + 50% inorganic fertilizer was next best treatment without significantly reducing the forage yield of sorghum and grain yield of gram in fodder - gram cropping sequence.

Tomar *et al.* (1996) studied on efficiency of phosphate solubilizing bacteria with phosphorus on growth and yield of gram. They concluded that increase in grain and straw yield was 2.37 and 3.59 q ha^{-1}, respectively owing to PSB inoculation. PSB synthesis growth promoting substances and produce vitamins, which augment plant growth. The interaction PSB x P level was found significant. The highest grain yield (38.87 q ha^{-1}) with using PSB with rock phosphate + pyrite and 60 kg $P_2 0_5$ ha^{-1}.

Dubey *et al.* (1997) reported that co-inoculation of *Bradyrhizobium Japonicam* and phosphate solublizing bacteria *Pseudomonas striata* alone and with super phosphate and rock phosphate increased the nodulation shoot weight and seed yield of soybean. Maximum seed yield (19.3 q ha^{-1}) was obtained with SSP @ 60 kg P_20_5 ha^{-1} + co-inoculation. The response of wheat crop to phosphorus solublizer was equivalent to 50 kg P_20_5 ha^{-1} as SSP. In addition PSB produce growth harmones i.e. IAA. auxins, gibberlins and vitamins which are also conducive to better nodulation, plant growth and yield of crops.

Pramila rani and Kodandaramaiah (1997) reported that substantial increase in yield of soybean was observed with Rhizobium treatments, irrespective of varying nitrogen level over no inoculation, however application of an initial booster dose of 30 kg N ha^{-1} coupled with seed inoculation gave significant higher seed yield than with only inoculated treatments due to increase in number of nodule / plant and nodule, dry weight, better development and higher dry matter accumulation and it's subsequent translocation to the seed. Seed inoculation with *Rhizobium japonicam* significantly increase the grain yield of soybean in all three years, the increase was 228,113 and 115%. The significant dry weight of nodules was obtained under N_{30}+ inoculation (552.3 mg), N_{120} + inoculation (531.4 mg) and N_{90} + inoculation (529.4 mg) which were at par statistically. However N_{30}+ inoculation recorded highest grain yield (2058 kg ha^{-1}) and was at par with N_{90} + inoculation (2218 kg ha^{-1}) and N_{120} + inoculation (2076 kg ha^{-1}).

Bobde *et al.* (1998) concluded that application of 7.5 tonnes FYM ha^{-1} along with reduced dose of fertilizer to 50% gave significantly more grain yield of soybean than absolute control and recommended dose of fertilizer. Succeeding crops viz. Indian mustard, wheat and gram taken after soybean gave 14.0, 132.2 and 107.2% extra monetary returns respectively, over no rabi crop after soybean. Inoculation with *Rhizobium japonicum* significantly increased the grain yield of soybean in all 3 years.

Singh *et al.* (1998) found that Rhizobium inoculation and incorporation of FYM increased significantly the grain yield of soybean in both the years over inoculated control. The increased in seed yield of soybean with inoculation of rhizobium appeared due to proper establishment and greater infection of rhizobium strains at more numbers of modules of site was evident from the higher number of modules and their weight which resulted in supply of 'N' in larger quantity to plant. The residual effect of rhizobium and FYM on grain yield of the succeeding wheat crop was significantly superior. Additionally grain yield of wheat on inoculation with rhizobium and application of FYM during Kharif might be due to increase in availability of 'N' in soil at different growth stages of soybean.

Ravankar *et al.* (1998) reported that the highest yield of succeeding wheat crop (1496 kg ha^{-1}) was obtained when it preceded with greengram, it was significantly higher than when it was preceded with pigeon pea or groundnut but it found at par when preceded with soybean. (1349 kg ha^{-1}). After harvesting legumes, the organic carbon and total N content in the green gram plots were actually slightly lower than the plots of soybean & groundnut. But yield of wheat was higher. This might be due to rapid decomposition and mineralization of green gram residues. The increasing levels of N from 15 to 45 kg ha^{-1} also increased the grain and straw yield of wheat to the extent of 29.56% and 24.10%, respectively.

Jain *et al.* (1999) studied on response of chickpea to phosphorus and biofertilizer and reported that seed inoculation with rhizobium and PSB resulted in 15 to 10 per cent higher seed yield over no inoculation. However, combined application of biofertilizer without phosphorus could not show any impact on the seed yield of chickpea over single inoculation of biofertilizer. but dual inoculation gave 16.1 per cent higher yield over no inoculation. Biofertilizer (Rhizobium + PSB) inoculation with 60 kg P_2O_5 ha^{-1} gave the highest seed yield being significantly higher over the same dose with no inoculation during both the years. Application of 45 kg P_2O_5 ha^{-1} with inoculation of biofertilizer (Rhizobium + PSB) gave significantly higher yield. With the application of 60 kg P_2O_5 ha^{-1}, increase in seed yield was to the level of 21.3 and 14.3 per cent during both the years. This clearly showed that, fertilizer P requirement of the crop was reduced when it was inoculated with biofertilizers.

Kumar and Prasad (1999) studied on soil fertility and yield as influenced by different legume wheat sequences that based on two seasons, wheat after blackgram recorded markedly higher yield over wheat after other legumes and rice. There was marked increase in wheat yield with each increment of N upto 75 Kg N ha^{-1}. The total production in terms of wheat equivalent yield clearly demonstrated the superiority of legume - wheat sequences as compared to rice-wheat sequence.

Babhulkar *et al.* (2000) studied on residual effect of long term application of FYM and fertilizers on soil properties and revealed that the highest seed and straw yields of soybean were obtained due to residual effect of application of 7.5 Mg FYM ha^{-1} with half dose of N and P which was 26.81 and 20.10 percent higher over control and recommended dose of N, P and Zn fertilizers. Further they concluded that amongst the cropping sequences, the highest seed and straw yields were recorded under gram followed by soybean respectively.

Kanwar and Paliyal (2002) revealed that, grain yield of chickpea was maximum at 50 kg P_2O_5 ha^{-1} along with FYM + vermicompost @ 10 t ha^{-1}.

FYM and vermicompost were equally effective in increasing grain yield. Grain yield of gram varied between 6.03 to 13.32 and 5.08 to 10.93 q ha^{-1} during both rabi season respectively. Maximum grain yield(13.32 q ha^{-1}) was obtained when 75 kg P_2O_5 ha^{-1} along with vermicompost and(12.17 q ha^{-1}) with 50 kg P_2O_5 ha^{-1} + FYM. 50 and 75 kg P_2O_5 ha^{-1} along with vermicompost found to be statistically at par during second year, however significant increase in grain yield of gram was obtained at 75 kg P_2O_5 ha^{-1} along with FYM as compared to the lower dose along with FYM.

Chaturvedi and Chandel (2005) studied on Influence of organic and inorganic fertilization on soil fertility and productivity of soybean, he found that, recommended dose of NPK + FYM 10 t ha^{-1} gave the maximum yield which found 25.7, 60.2, 94.9, 84.7, and 48.0% higher over the recommended NPK, 50% recommended NPK, boron @ 2.0 kg ha^{-1}, iron @ 5.0 kg ha^{-1} and FYM @ 10 t ha^{-1} respectively. Application of FYM @ 10 t ha^{-1} with 50% NPK recorded more yield that recommended NPK dose when applied alone. This emphasized the need for organic manuring along with chemical fertilizer.

Gawai and Pawar (2005) studied on yield and yield components of sorghum as influenced by integrated nutrient management system and its residual effect on chickpea. He observed that, residual effects of INMS to sorghum was not significant in respect of yield component and yield of chickpea however, the treatments 50% RDF + FYM was numerically better than rest of the treatments. The nodule count of chickpea showed higher value where FYM was combined with reduced levels of RDF. The graded levels of RDF to chickpea resulted in significantly higher value of yield of chickpea due to 100% RDF. However, 50% RDF was at par with 100% RDF in respect of grain yield of chickpea.

Saini *et al.* (2005) revealed that, multi inoculation of bio -inoculants along with chemical fertilizer recorded maximum grain (2.22 t ha^{-1}) and stover (3.75 t ha^{-1}) yield of soybean which are significantly higher than control and sole application of FYM. Further grain and stover yield of treated plots with 100% recommended N and P found statistically at par with the treatment where half dose of nitrogen is substituted by N_2 - fixers. This indicated that 50% N requirement of crop plant was met by applied bio – inoculants, so it clearly indicated that, to obtain maximum crop yield 50% of the chemical fertilizers could be substituted with suitable bio - inoculants.

Kalwe and Rani (2005) studied on nutrient management in soybean and pooled analysis of the three years data revealed that the application of FYM resulted in significantly highest seed yield. Seed yield increased significantly with the application of nitrogen combined with organic sources. Significantly maximum seed yield was found with (25 kg N + 5 tonnes of FYM ha^{-1}, 25 kg N + 1t neem cake ha^{-1} and recommended NPK (20:60:40). Further it was observed that the application of FYM and fertilizer P significantly increased the grain yield of soybean. The effect of FYM on soybean yield was significant up to 8 t ha^{-1} and fertiliser P increased the same up to 22 kg P ha^{-1}. Apparently response to each nutrient depend on supply of other nutrients and such interactions should be exploited for maximum benefit of crop growth and yield through balanced plant nutrition.

Deshmukh *et al.* (2005) also reported that 100% RDF along with 2.5 t FYM ha^{-1} and drainage in soybean and soil mulch in chickpea recorded the highest yield in soybean chickpea cropping system, indicating that addition of organic along with 100% RDF is necessary for higher productivity of soybean.

Billore *et al.* (2006) revealed that, application of FYM + RDF (20 : 26 :17 NPK kg ha^{-1}) and RDF (120 : 26 : 30 NPK kg ha^{-1}) + hand weeding sustained the soybean-wheat system productivity through long term fertilizer application. Application of N,NP and NPK could raise the yield of soybean by 14.3, 10.3 and 16.1%, respectively however, corresponding increase in wheat was 74.0, 83.0 and 79.0%. The increase in soybean yield through 50% and 100% recommended NPK recorded 2.0 and 16.1% while that in wheat was 49.2 and 79.0%. The integration of NPK with FYM could further enhance the yield levels by 26.03 and 90.58% in soybean and wheat, respectively.

Choudhary *et al.* (2008) reported that, grain yield of chickpea was the highest in the treatment RDF which was at par with FYM @ 5 t ha^{-1} + seed treatment of soil application of Rhizobium and PSB, vermicompost @ 3 t ha^{-1} + seed treatment or soil application of Rhizobium and PSB, and significantly superior over the treatments FYM @ 5 t ha^{-1}, vermicompost @ 3 t ha^{-1} 1/2 RDF (12.5:25:00 kg NPK ha^{-1}) + Rhizobium and PSB as seed treatment and 1/2 RDF + Rhizobium and PSB as soil application. However, the straw yield was maximum under FYM @ 5 t ha^{-1} + Rhizobium and PSB seed treatment which was at par with RDF, FYM @ 5 t ha^{-1} with Rhizobium and PSB as soil application significantly superior over rest of treatments. This might be due to slow and insufficient availability of nutrient from FYM or vermicompost and reduced dose of inorganic fertilizer, whereas full RDF or organic manure coupled with dual inoculation of biofertilizers might have directly catered to the need of various plant nutrients of the crop in sufficient quality.

Gable *et al.* (2008) studied the effect of integrated nutrient management on growth and yield of maize-chickpea cropping system. Application of half recommended dose of fertilizer to chickpea improved the growth parameters and yield of chickpea and also significantly higher than no application of fertilizers. The residual effect of preceding INM treatments on chickpea yield was not significant to both the treatment consisting no fertilizers and 50% RDF. Application of half RDF (12.5:25:00 kg NPK ha^{-1}) to succeeding chickpea in addition to INM to maize, enhanced the yield significantly over control i.e. residual effect of INM given to maize alone. Although the interaction effect was found non-significant. Treatment combination of residual effect of 75% RDF + 25% through leucaena lopping + biofertilizer (Azotobacter) applied to maize and 50% RDF to chickpea recorded higher yield value than any other combinations.

Shivakumar and Ahlawat (2008) studied on integrated nutrient management in soybean-wheat cropping system. He found after the pooled analysis of three years data, that the combined application of 5 t ha^{-1} each of crop residues, FYM and 5 kg ha^{-1} of zinc recorded significantly higher seed yield (1.48 t ha^{-1}) stover yield (4.06 t ha^{-1}) and harvest index (36.4%). It was closely followed by application of 5 tha^{-1} FYM alone. Application of 100% RDF recorded significantly higher seed yield (1.55 t ha^{-1}), stover yield (4.35 t ha^{-1}) and harvest index (35.5). As there was an ideal condition for soil microflora due to application of crop residues and FYM along with zinc and increased availability of nutrients with 100% RDF, there was improvement in both growth and yield attributes, which in turn might have increased the yield of soybean. Similarly 100% RDF applied to the previous soybean recorded significantly higher growth and yield attributes and yield of wheat among the different nutrient levels. The nutrient sources due to slow and gradual decomposition show residual effect and thus might have improved the performance of wheat after soybean. Thus nutrient sources and levels applied to soybean on wheat showed significant residual effect.

Thakur and Sawarkar (2009) studied on influence of long term continuous application of nutrients and spatial distribution of sulphur on soybean-wheat cropping sequence and concluded that maximum yield of soybean and wheat (1860 and 5775 kg ha^{-1} respectively) were recorded with application of 100% NPK and FYM @ 15 t ha^{-1} as compared to other treatments and over control. The reasons for increased response to FYM are generally ascribed to beneficial effect associated with soil productivity.

2.5 Concentration and uptake of major nutrients

Nimje and Seth (1988) studied on effect of phosphorus and farmyard manure on nutrient uptake by soybean. They observed that, content and uptake of major nutrients at harvesting stage significantly enhanced due to increasing levels of phosphorus and farmyard manure. The increased in the fertilization might be due to enhanced symbiotic nitrogen fixation and improved growth of symbiotic nitrogen plant. Application of farmyard manure to soybean crop also proved beneficial in enhancing the N. P. and K content of grain, stover and husk to an appreciable extent due to greater availability of nutrients to plant in presence of organic manures.

Sharma and Bajpai (1989) reported that, the uptake of nitrogen by grain and straw of wheat significantly increased due to the cultivation of preceding kharif legume as compared to fallow soil or cereal crop. Nitrogen uptake of 91.23 and 92.75 kg ha^{-1} was noticed in the grain of wheat and gram, respectively as compared with 82.09 kg ha^{-1} in fallow soil and 85.31 kg ha^{-1} in sorghum. As regards the main effect of nitrogen and its uptake in grain and straw of wheat increased significantly up to the level of 120 kg N ha^{-1}.

Pandagre *et al.* (1992) studied the effect of different level of N, P and K on nutrient content of wheat. Application of nutrients influenced their content in grain and straw. The highest nitrogen and phosphorus content were in grain and straw (2.132%) and (0.240%) (0.370% N) and (0.128% P) respectively at higher level of N_{120} P_{80} which is found significantly superior over other treatments but the effect of K was found to be non significant. The maximum uptake of N and P_2O_5 was recorded in grain (58.38 and 16.17) and straw (13.92 and 8.25) kg ha^{-1} with nutrient receiving recorded in N_{120}

P_{80}. This is probably due to increase in dry matter production per unit area with fertilizer doses.

Singh and Tiwari (1995) observed that the differences in N uptake by each crop and cropping sequence were significant. On the basis of individual crop, legumes either soybean or gram or lentil crop removed significantly higher quantity of nitrogen during both the years. This is due to the fact that fixation and self utilization of the atmospheric nitrogen and the transformation of the same in proteinaceous grains might have resulted in maximum harvest of nitrogen. Gram grown after soybean remove more nitrogen than lentil. This might have happened due to higher biomass production by gram than lentil. Significant differences were recorded in the uptake of P and K by different crops during both the years. Soybean-gram system removed the highest quantity of phosphorous and potassium followed by soybean-safflower. More removal of these nutrients is due to intensive roof-system as well as capacity to change in available form.

Santhy *et al.* (1998) revealed that, total uptake of N. P and K increased with progressive increase in the supply of NPK to the crop because of higher availability of these nutrients. Application of NPK at 100% of optimum level along with FYM at 10 t ha^{-1} increased the uptake greatly as compared to the application of 100% NPK alone. In the absence of P application (N alone and control) considerable reduction in P uptake was noticed due to the P becoming limiting nutrient and consequently lower biomass production. The highest K uptake was 100% NPK with FYM followed by 150% optimal NPK.

Subbarao *et al.* (1998) studied on crop yield and phosphorus recovery in soybean – wheat cropping system on a typic haplustert under integrated use of manures and fertilizer phosphorus. He further observed that phosphorus up to 44 kg P ha^{-1} +16 t FYM recorded significantly higher P uptake (21.85 kg ha^{-1}) in soybean than other combinations. The favourable effect of FYM on P uptake may be attributed to greater availability of phosphorus to plants in the presence of organic manure and to its solublizing effect on fixed forms of P in soil. Total phosphorus uptake by wheat increased progressively with rates of application of both FYM and phosphorous. The highest uptake (14.38 kg ha^{-1}) was observed with addition of 16 t FYM and 44 kg P ha^{-1}.

Sawarkar *et al.* (1999) reported that total phosphorus uptake by soybean was more as compared to wheat crop in soybean - wheat cropping sequence. The P uptake decreased with the harvest of the subsequent crop ,this reduction was continuous in wheat crop, while in case of soybean the reduction of P uptake was observed at the harvest of 3^{rd} crop onward, the reduction from 15.16 to 10.58 and 14.40 to 10.82 kg P ha^{-1} in the medium gradient and 17.09 to 10.83 and 16.04 to 12.63 kg P ha^{-1} in high P gradient for soybean and wheat crop, respectively. This reduction in total phosphorous uptake might be due lowering of Olsen's P level.

Kanwar and Paliyal (2002) studied the influence of phosphorus management and organic manuring on uptake and yield of chickpea. He observed that, P uptake was maximum i.e.7.39 kg ha^{-1} at 50 kg P_2O_5 ha^{-1} with FYM and 7.85 kg ha^{-1} at 75 kg P_2O_5 ha^{-1} along with vermicompost. Increasing levels of P_2O_5 alone or along with organic manures (FYM or vermicompost) increased the uptake of P uptake ranged from 3.63 to 7.87 kg ha^{-1} in the first year and 3.33 to 7.85 kg ha^{-1} in the second year

Gajbhiye (2004) studied on the effect of INM on fertility, yield and quality of soybean. He found that, nitrogen content in seed (6.83%) and dry matter (1.11%) were highest in treatment received 75% RDF + Rhizobium + PSB was superior, followed by full RDF dose. The phosphorus content in seed (0.572%) and dry matter(0.175%) were highest at 75% RDF +

Rhizobium + PSB followed by 50% RDF + Rhizobium + PSB and full dose RDF. The highest potassium content in seed (0.57%) observed with 50% RDF + 50% N through vermicompost and highest potassium in dry matter of soybean (0.913%) was observed with treatment 50% RDF + 50% N through vermicompost.

Jain and Singh (2003) reported that, inoculation by Rhizobium + PSB and phosphorus significantly increased nitrogen content in grain (3.68%) as well as in straw (1.25%). The per cent increase was 12.8 to 14.6 and 13.7 to 9.0% respectively in grain and straw due to Rhizobium + PSB inoculation and 50 kg P_2O_5 ha^{-1} over their respective control. The uptake of both the nutrients N and P by the crop was markedly influenced by the use of biofertilizers and phosphorus fertilization. The total uptake of N and P was 45.1 and 63.6 per cent higher with Rhizobium + PSB and 52.5 and 62.5 per cent with 50 kg P_2O_5 ha^{-1}, respectively over control.

Tanwar and Shaktawat (2003) studied on the effect influence of phosphorous sources, levels and solubilizers on yield, quality and nutrient uptake of soybean-wheat cropping system in Southern Rajasthan and concluded that application of 38.7 kg P ha^{-1} increased the seed yield and N and uptake of soybean by 13.3, 18.7 and 30.5% over 12.9 kg P ha^{-1} respectively. The maximum productivity and N and P uptake of succeeding wheat and system as a whole were recorded at 38.7 kg P ha^{-1} application to soybean. An incorporation of farm yard manure @ 10 tonnes ha^{-1} with and without phosphorous solubilizing bacteria significantly improved the yield (9.3 and 7%) quality and N (17.8 and 13.2%) and P (17.5 and 13.4%) uptake of soybean and yield (9.6 and 7.5%), N (16.7 and 13.6%) and P uptake (15.9 and 12.3%) of succeeding wheat crop and hence the yield of system as whole (9.5 and 7.3%) respectively over phosphorous solubilizing bacteria alone. Application of 25.8 kg P ha^{-1} to wheat crop improved its yield (13.8%)

with RDF (40.36 kg ha^{-1}) and FYM @ 5 t ha^{-1} + Rhizobium and PSB as seed treatment (40.04 kg ha^{-1}). Application of organic manures and biofertilizers might have enhanced the availability of nutrients to the crop leading to their increased content in grain and straw.

Thakur and Sawarkar (2009) reported that, the uptake of NPK and S were recorded significantly in the treatment that had received recommended dose of fertilizer when applied with organic manure i.e. FYM @ 15 t ha^{-1} over the control 239.9, 13.8, 113.8, 11.9 kg ha^{-1} for soybean and 254.9, 24.9, 79.6, 7.8 kg ha^{-1} for wheat. This might be owing to increased supply of nutrient sources to the crop, as well as due to the indirect effect resulting from reduced loss of organically supplied nutrients.

2.6 Balance sheet of nutrients

Ghosh *et al.* (1995) reported that the balance sheet of N, P and K revealed that the continuous application of 20 kg N, 35.2 kg P, 33.2 kg K along with 10 tonnes FYM ha^{-1} soybean and wheat (grown on residual fertility) had maintained most favorable nutrient balance in the soil.

Singh and Tiwari (1995) reported that soybean-gram and soybean-lentil removed maximum amount of nitrogen and phosphorous, whereas, soybean-gram and soybean-safflower removed maximum amount of potassium.

Chapter III

MATERIAL AND METHODS

The field investigation in relation to "Effect of Integrated Input Management on Nutrient Balance under Soybean based cropping System" was conducted during Kharif-Rabi season of 2009-10 at Extra Assistant Director (EAD) farm, College of Agriculture, Nagpur. The details of materials used and methods adopted during the period of investigation are given in this chapter under appropriate heads.

3.1 Basic resources information

3.1.1 Experimental site

The field experiment entitled "Effect of Integrated Input Management on Nutrient Balance under Soybean based cropping System" was carried out at Extra Assistant Director (EAD) Farm, College of Agriculture, Nagpur. The field selected for conducting the experiment was fairly uniform and levelled.

3.1.2 Soil of experimental area

The soil under the experiment area was medium in depth and well drained. In order to study the chemical properties of soil, a composite soil sample was taken from 0-30 cm depth, from randomly selected plots over the experimental field before sowing. The composite soil sample was analyzed for various chemical properties in order to asses the initial fertility status of soil. The chemical properties of soil are determined in laboratory and the results are presented in table along with method adopted for each parameter.

Table 1: Initial soil properties of experimental site

Sr. No.	Properties	Value
A)	**Mechanical Analysis**	
1)	Sand %	20.5
	a) Course Sand %	14.1
	b) Fine sand %	6.4
2)	Silt %	23.0
3)	Clay%	56.5
A)	**Chemical properties**	
1)	pH	7.68
2)	EC(dSm^{-1})	0.303
3)	Available N (kg ha^{-1})	296.91
4)	Available P_2O_5 (kg ha^{-1})	26.58
5)	Available K_2O, (kg ha^{-1})	390.82
6)	Organic carbon, (g kg^{-1})	7.06
7)	Available S (kg ha^{-1})	8.20
8)	Exchangeable Ca^{++} (cmol(p^+)kg^{-1})	53.45
9)	Exchangeable Mg^{++} (cmol(p^+)kg^{-1})	15.46
10)	DTPA Extractable micronutrient	
1)	DTPA Fe(mg kg^{-1})	3.90
2)	DTPA Mn(mg kg^{-1})	2.53
3)	DTPA Zn(mg kg^{-1})	0.58
4)	DTPA Cu(mg kg^{-1})	1.30

3.1.3 Description of soil

The soil of the experimental field was clay in texture. The results of chemical analysis indicate that soil was medium in available nitrogen moderately high in available phosphorous, very high in available potassium and moderately high in organic carbon. Soil pH was 7.85 and EC recorded 0.303 dSm^{-1}.

3.1.4 Climate and weather conditions

Nagpur is situated at 21° 10' North latitude, 79° 19' East latitude at elevation of 312.26 m above sea level and lies under subtropical zone. Nagpur is characterized by hot and dry summer and fairly cold winter. This area shows wide diurnal fluctuations in temperature. The maximum and minimum temperature ranged from 34.2 to 9.9°c respectively whereas relative humidity varied from 17% to 82% during the crop growth period. Mean annual precipitation was about 928.8. The meteorological data in respect of rainfall, humidity maximum and minimum temperature during course of study for the period from June to December 2009 and Jan 2010 to April 2010 are furnished in Appendix.

3.2 Experimental Details

3.2.1 Design of Experiment and treatments

The Experiment was laid out in strip plot design with three modules replicated by four, the details of treatment are presented below, the plan of layout giving the relevant details is also presented in fig- 1.

Location	-	Extra Assistant Director (EAD) Farm College of Agriculture Nagpur.
Crops	-	Soybean
		Wheat
		Gram
Varieties	-	Soybean (JS - 335)
		Wheat (AKW - 1071)
		Gram (AKG - 46)
Spacing	-	Soybean - 45 x5 cm
		Wheat – 22.5 cm
		Gram – 30 x 10 cm
Season	-	2009 – 2010 Kharif and Rabi
Number of replication	-	Four
Number of treatments (plots)	-	24
Experimental Design	-	Strip plot design
Number of Modules	-	Three
		i) Organic

		ii) Inorganic
		iii) Integrated
Plot Size	:	Gross – 4.5 m x 6.0m
		Net - 3.6 m x 5.4 m
Method of sowing	:	Dibbling and drilling wheat
Date of sowing	:	Kharif soybean 13/07/2009
		Rabi 1. Wheat-11/11/2009
		2. Gram -11/11/2009
Date of harvesting	-	Soybean 11/10/2009
		Wheat 3/04/2010
		Gram 3/04/2010
Experiment started	-	2005

Treatment details

Soybean- Module - I : Organic

Seed treatment: *Rhizobium* ,PSB, 25 g kg^{-1} *Tricoderma viride* 4 g kg^{-1}

a) FYM 5t ha^{-1}+ vermicompost 2.5 t ha^{-1}
b) Weed control : 2 hoeing up to 45 DAS if required 1 to 2 weeding.
c) Plant protection : at ETL 5% Neemarc, mechanical, cultural and biological pest and disease control, collection and destroying infested plant parts and plants.

Module - II : Inorganic

Seed treatment , Thirum 3g kg^{-1} of seed.

a) RDF 30 : 75: 0 kg NPK ha^{-1} at the time of sowing.
b) Weed control : PPI fluchloralin 1 kg a.i. per ha or trifluraline 1 kg a.i. ha^{-1} or PE Alachlor 2 kg a.i. or Metachlor 1 kg a.i. or pendimethaline 1 kg a.i. ha^{-1} +1 hoeing +1 weeding it required.
c) Plant protection: 10 kg phorate (10% granules) ha^{-1} Dimethoate 10 ml or Endosulfan 17 ml or monocrotophos 15 ml or quinolphos 20 ml.

Module - III : Integrated input management

a) Seed treatment: Rhizobium, PSB, and 25 g kg^{-1} Tricoderma viride 4 g kg^{-1} or Thirum 3 g kg^{-1}.

b) FYM 5 t ha^{-1} or vermicompost 2.5 t + half RDF (15 : 37.5 : 0 kg NPK ha^{-1}) at the time of sowing.

c) Weed control: PPI Fluchloraline 1.5 kg a.i. ha^{-1} Trifluraline 1.5 kg a.i. ha^{-1} or PE Alachlor 1 kg Metachlor 0.75 kg a.i. or Pendamethaline 0.75 kg a.i.ha^{-1} +1 hoeing + 1 weeding.

d) Plant protection: cultural and mechanical methods of plant protection, control measures taken at ETL 5% Neemarc, Dimethoate 10 ml or Endosulfan 17 ml or Monocrotophos 15 ml or quinolphos 20 ml.

Wheat- Module – I : Organic

a) Inoculation with PSB and Azotobactor. FYM @ 5 t ha^{-1} +Vermicompost @ 2.5 t ha^{-1} or FYM @ 10 t ha^{-1} weed control through cultural practices and mechanical and by bioagents.

Module – II : Inorganic

a) Seed treatment with recommended fungicide. Recommended dose of fertilizer (100:50:50) and weed control through recommended practice.

Module - III : Integrated input management

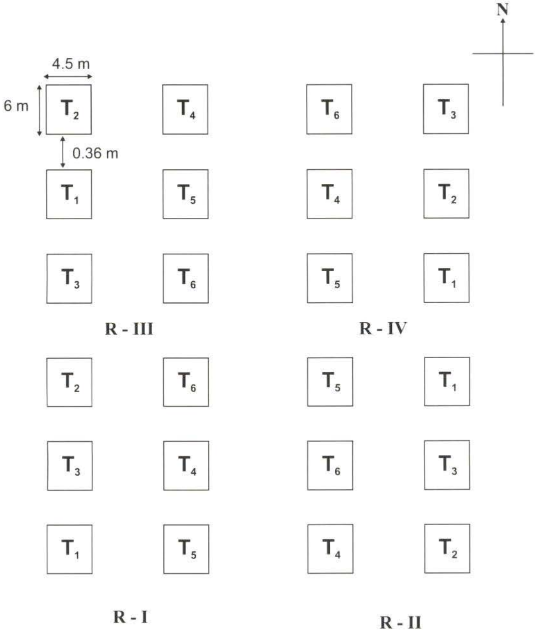
a) Inoculation with PSB, Azotobacter and Fungicide, FYM @ 5 t ha^{-1} or Vermicompost 2.5 t ha^{-1} + 50% RDF(50:25:25). weed control through preemergence herbicide + one hand weeding and plant protection measure through IPM practice.

Gram – Module- I : Organic

Inoculation with Rhizobium. FYM @ 5t ha^{-1}. weed control through cultural practices and mechanical and by bioagents.

Module - II : Inorganic

Seed treatment with recommended fungicide, Recommended does to fertilizer (25:50:00) and weed control through recommended herbicide and plant protection through recommended practice.



Design : Strip Plòt Design
Gross Plot : 4.5 m x 6.0 m
Net Plot : 3.6 m x 5.4 m
T_1 - SWO
T_2 - SWI
T_3 - SWITG
T_4 - SGO
T_5 - SGI
T_6 - SGITG
R - Replication - 4
T - Treatment - 6

Fig. 1 - Plan of Layout

Module - III : Integrated input management

Inoculation with PSB, Rhizobium and fungicide, FYM @ 5.0 t ha^{-1} or Vermicompost @ 2.5 t ha^{-1} + 50% RDF(12.5:25:00) weed control through pre-emergence herbicide + one hand weeding /hoeing at 25 - 30 DAS and plant protection.

3.2.1 Design of Experiment and treatments

3.3 Soil and plant sampling

3.3.1 Soil sampling

A composite soil sample (0-30 cm depth) before sowing of crop was taken from the experimental area. The soil samples were dried in shade and gently grind with pestle and mortar and sieved through 2 mm sieve. Those samples were stored in polythene bags and were subsequently analyzed for pH, EC, organic carbon available N, P, K, S, Ca, Mg and DTPA - extractable micronutrients (Fe, Mn, Zn and Cu).

3.3.2 Plant sampling

Plant samples from the 24 plots were separately collected and while taking the samples from each individual plot, technique of randomization is used. Five plants were selected from each plot and dried in an electric oven at a temperature 65°C, and oven dried samples were finely poured (100 mesh) and grinded by machine and requisite quantity of samples were analyzed for its N, P, K, S and Fe, Mn, Zn and Cu content.

3.4 Methods of Analysis

3.4.1 Soil Analysis

3.4.1.1 Chemical properties

a) Soil reaction (pH)

The pH was determined in 1:2.5 soil water suspension using digital pH meter (Piper, 1966).

3.5 Yield studies

The sun dried plants of each net plot were threshed, cleaned and weigh it. Net plot yield and yield per hectare was calculated separately.

3.5.1 Wheat equivalent yield

Wheat equivalent yield is calculated by following formula.

$$\text{Wheat equivalent yield q/ ha} = \frac{\text{yield of crop (gram)} \times \text{prize per (q) of produce b(gram)}}{\text{prize per (q) of produce a (wheat)}}$$

3.6 Statistical analysis

Standard method of analysis known as 'Analysis of Variance' was applied for the standard analysis of the data. Critical difference (CD) at 5% level of significance was worked out and used for comparison of different treatments (Gomez and Gomez, 1983).

Chapter IV

RESULTS AND DISCUSSION

Agriculture is the backbone of Indian economy, which is facing serious threat like declining partial and total factor productivity (TFR), deterioration in soil health and quality, declining soil fertility and soil resilience. There is a declining trend in total organic carbon and NPK content in the soil. Earlier major nutrients like N was only deficient but now a days multiple nutrient deficiency (MND) has also become a cause of concern as it is a stumbling block in achieving the genetic potential of HYV's. For partial substitution of inorganic fertilizers important practice like crop residue management, organic matter enrichment through organic waste recycling, agro-industrial waste utilization etc. are beneficial.

Along with this the agricultural practices like balanced and integrated use of plant nutrient sources, adoption of suitable cropping systems like introducing legumes in rotation with cereals, use of organic manures and farm wastes and biofertilizers are well known ways to prevent decline in the fertility of intensively cultivated soils. Thus improving efficiency of applied nutrients is of paramount importance in the context of resource conservation.

The component crops in a system may have different protocol of nutrient management than considered individually. This necessiates readjustments in scheduling of nutrient management for a cropping system. Conventional analysis of variance for each year is not likely to provide the overall assessment of the system stability on account of complexity of factors of prevailing environments.

In the present study the results of the present investigation entitled, "EFFECT OF INTEGRATED INPUT MANAGEMENT ON NUTRIENT BALANCE UNDER SOYBEAN BASED CROPPING SYSTEM", the various observations recorded during the course of study and data generated were subjected to statistical analysis, discussed in detailed and valid conclusions were drawn under following appropriate heads.

4.1 Grain and straw yield of soybean, wheat and gram.

4.2 Content and uptake of major nutrients by soybean, wheat and gram.

4.3 Content and uptake of micronutrients by soybean, wheat and gram.

4.4 Availability of major nutrients after harvest of kharif and rabi crops.

4.5 Availability of micronutrients after harvest of kharif and rabi crops.

4.6 Chemical properties of soil after harvest of soybean, wheat and gram.

4.7 Balance sheet of nutrients.

4.1 Grain and straw yield of soybean, wheat and gram

4.1.1 Grain and straw yield of soybean

The data regarding to grain and straw yield of soybean as affected by cropping system are depicted in table 2.and graphically illustrated in fig 2. Results indicated that the grain yield and straw yield of soybean were found significant due to various cropping system. Highest grain yield (14.76 q ha^{-1}) and straw yield (21.89 q ha^{-1}) were observed in soybean-gram cropping system.

With the input management modules, the grain yield and straw yield of soybean observed statistically significant. The highest grain yield of soybean (15.41 q ha^{-1}) was obtained with the application of 50% RDF coupled with FYM @ 5 t ha^{-1} + biofertilizer (integrated module) whereas straw yield of soybean was also recorded higher (21.72 q ha^{-1}) under integrated module which is significantly superior over organic and inorganic module. There is an increase in trend of grain and straw yield of soybean due to combination of both organic and inorganic fertilizer.

Table 2 : **Grain and straw yield of soybean as influenced by cropping system with input management modules (after completion of 5th cycle)**

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
Cropping system						
Soybean – wheat	11.97			17.84		
Soybean – gram	14.76			21.89		
SE (m) ±	0.168			0.248		
CD at 5%	0.504			0.744		
Input management modules						
Organic module (M-I)	11.60			17.96		
Inorganic module (M-II)	13.11			19.92		
Integrated module (M-III)	15.41			21.72		
SE (m) ±	0.197			0.292		
CD at 5%	0.591			0.876		
Interaction (Cropping system x modules)						
	M - I	**M – II**	**M - III**	**M - I**	**M – II**	**M - III**
Soybean – wheat	10.65	12.42	12.85	16.49	17.51	19.53
Soybean – gram	12.54	13.36	18.39	19.44	20.30	25.93
SE (m) ±	0.285			0.419		
CD at 5%	0.855			1.257		

The interaction of Bradyrhizobium with different crop cultivars to modulation is of great concern. There is the beneficial effect of Rhizobium inoculation on N-economy and the crop production. It was observed that by inoculation with efficient strain of *B. japonicum* may give additional yield. Seed inoculation provides adequate availability of N during reproductive stage of the crop that results in increased grain yield. Thus integration of inorganic, bacterial inoculation and organic manures provide conducive environment for the proper establishment of Rhizobuim and growth of modules or N-fixation and enhances the yield.

Table 3 : Grain and straw equivalent yield of wheat as influenced by cropping system with input management modules(after completion of 5th cycle)

Treatments	Wheat equivalent grain yield (q ha^{-1})			Wheat equivalent straw yield (q ha^{-1})		
Cropping system						
Soybean – wheat	28.86			43.52		
Soybean – gram	22.04			42.55		
SE (m) ±	0.261			0.405		
CD at 5%	0.783			NS		
Input management modules						
Organic module (M-I)	25.17			42.68		
Inorganic module (M-II)	25.75			43.06		
Integrated module (M-III)	25.44			43.37		
SE (m) ±	0.122			0.266		
CD at 5%	0.366			NS		
Interaction (Cropping system x modules)						
	M - I	**M – II**	**M - III**	**M - I**	**M - II**	**M - III**
Soybean – wheat	28.63	29.14	28.81	43.17	44.10	43.29
Soybean – gram	21.71	22.35	22.07	42.19	42.02	43.45
SE (m) ±	0.409			0.760		
CD at 5%	NS			NS		

Application of FYM and soybean residue each @ 5 t ha^{-1} proved to be superior in enhancing the yield of crop in soybean-wheat system might be accounted for beneficial effect of FYM and residues on nutrient transformation and supplying capacity of the soil.

The interaction effect between cropping system and input management module in case of wheat equivalent grain yield and wheat equivalent straw yield was found non significant .Wheat equivalent grain yield was recorded (29.14 q ha^{-1}) with the application of 100% RDF (inorganic module) which

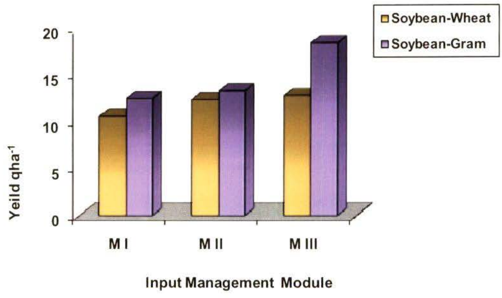


Fig2: Interaction between cropping system with input management module on grain yield of soybean

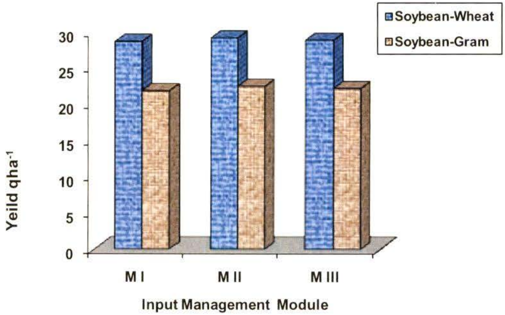


Fig 3: Interaction between cropping system with input management module on grain equivalent yield of Wheat

attained higher over soybean gram sequence in the same module. Similarly wheat equivalent grain yield in soybean-wheat sequence was recorded (28.81 q ha^{-1}) with the application of 50% RDF along with FYM @ 5 t ha^{-1} which was higher over soybean-gram sequence. Lower wheat equivalent grain and straw yield was obtained under organic module in both the cropping sequence but in case of soybean wheat cropping sequence it has been found statistically at par with integrated module in the same cropping sequence.

Wheat equivalent yield of straw under soybean-wheat sequence recorded higher under organic and inorganic module whereas it is recorded higher in integrated module under soybean-gram sequence. This clearly bring out the impact of integrating inorganic fertilizer with organic manure and bio-fertilizers.

Chitale *et al.* (2003) also reported equivalent yield of soybean wheat system. In rabi season, rice equivalent yield of wheat was maximum in soybean-wheat sequence with 100% RDF for the crop was due to carry over of N for succeeding rabi cereals crop and adding adequate nutrients to soil by organic manure.

4.2 Content and uptake of major nutrients by soybean, wheat and gram

4.2.1 Content and uptake of Nitrogen by soybean

The results associated with the concentration of N in grain and straw and its uptake by soybean plant is depicted in table 4. Nitrogen concentration of grain and straw of soybean plant at harvest stage was attained non-significant with cropping system. From the data it revealed that after completion of the 5th cycle significant differences were observed on total uptake of N by soybean under various cropping systems and it is recorded higher (124.70 kg ha^{-1}) under soybean-gram cropping sequence.

Among the input management modules the results with respect to N content in grain and straw and their uptake by soybean crop were found significant. Maximum concentration of N in grain (6.84%) was under integrated module which was at par with organic and inorganic module (6.66% and 6.76%), respectively. Higher concentration of N in straw was noted (1.17%) with treatment consisting inorganic input management which remained at par with integrated management module (50% RDF + FYM @ 5 t ha^{-1}). The increase in content of N in plant was due to addition of balance nitrogen in soil.

Nimje and Seth (1988) revealed that the application of 20:40:40 kg NPK ha^{-1} + FYM @ 15 t ha^{-1} to soybean proved beneficial in enhancing N content in straw (3.0%) at flowering stage to an appreciable extent due to greater availability of nutrients to plants in presence of organic manure and due to its solubility effect on fixed form of nutrient in soil.

Table 4 : Content and uptake of Nitrogen by Soybean as influenced by cropping system in combination with various management modules (after completion of 5th cycle)

Treatments	Nitrogen Content						Total N uptake (kg ha^{-1}) (grain+straw)		
	grain (%)			straw (%)					
Cropping system									
Soybean – wheat	6.76			1.12			101.18		
Soybean – gram	6.74			1.13			124.70		
SE (m) ±	0.048			0.028			0.622		
CD at 5%	NS			NS			1.866		
Input management modules									
Organic module (M-I)	6.66			1.04			96.00		
Inorganic module (M-II)	6.76			1.17			111.98		
Integrated module (M-III)	6.84			1.16			130.84		
SE (m) ±	0.025			0.016			1.691		
CD at 5%	0.075			0.048			5.093		
Interaction (Cropping system x modules)									
	M - I	**M - II**	**M - III**	**M - I**	**M – II**	**M - III**	**M - I**	**M - II**	**M - III**
Soybean – wheat	6.67	6.78	6.85	1.03	1.17	1.15	88.13	110.09	105.31
Soybean – gram	6.65	6.75	6.84	1.05	1.16	1.18	103.87	113.86	156.37
SE (m) ±	0.024			0.049			2.560		
CD at 5%	NS			NS			7.680		

Total uptake of N was found significant in various input management modules and it was recorded higher (130.84 kg ha^{-1}) in an integrated module which has received 50% RDF + FYM @ 5tha^{-1} + biofertilizers. Chaturvedi et al (2005) reported results on two year study, total uptake of N was observed increased with the 50% NPK + FYM @ 10tha^{-1} to soybean which attained at par with recommended dose of NPK indicating the benefits from integrated and balanced used of fertilizers.

Interaction effect between the main plat cropping system and sub plat input management modules on conc of N in grain and straw exhibited non significant difference. Total uptake of N shows significant difference and recorded higher (156.37 kg ha^{-1}) in an integrated module under soybean grain cropping sequence. Recommended dose of fertilizer when applied with organic manure i.e. FYM @ 15 t ha^{-1} recorded significantly highest total uptake of N might be due to increased supply of nutrient sources to the crop as reported by supply of nutrient sources to the crop as reported by Thakur and Sawarkar (2009).

4.2.2 Content and uptake of Nitrogen by wheat and gram

The data in respect of cone of N in grain and straw and its total uptake by wheat and gram are reported in table 5.

Table 5: Content and uptake of Nitrogen by wheat and gram as influenced by cropping system in combination with various management modules (after completion of 5th cycle)

Treatments	Nitrogen content						Total N uptake (kg ha^{-1}) (grain+straw)		
	grain (%)			straw (%)					
Cropping system									
Soybean – wheat	1.74			0.21			58.22		
Soybean – gram	3.22			1.11			59.03		
SE (m) ±	0.051			0.007			1.114		
CD at 5%	0.153			0.021			NS		
Input management modules									
Organic module (M-I)	2.42			0.62			54.68		
Inorganic module (M-II)	2.53			0.70			61.82		
Integrated module (M-III)	2.48			0.67			69.37		
SE (m) ±	0.029			0.023			0.498		
CD at 5%	NS			NS			1.494		
Interaction (Cropping system x modules)									
	M - I	**M - II**	**M - III**	**M - I**	**M – II**	**M - III**	**M - I**	**M - II**	**M - III**
Soybean – wheat	1.68	1.79	1.75	0.19	0.23	0.22	55.47	60.89	58.28
Soybean – gram	3.16	3.27	3.22	1.05	1.17	1.12	53.88	62.75	60.47
SE (m) ±	0.048			0.025			0.948		
CD at 5%	NS			NS			NS		

Content of N in grain and straw were found significant except its total uptake of N by wheat and gram was found non significant. Content of N in grain of gram recorded higher (3.22%) whereas wheat recorded (1.74%) N under soybean based cropping system. Whereas content of N in straw of gram recorded higher (1.11%) and wheat recorded (0.21%) N under soybean based cropping system.

In respect of different input management modules the mean value of N content in grain and straw was found non significant whereas total uptake of N by wheat and grain was found significant.

Total uptake of N was found highest (69.37 kg ha^{-1}) in an integrated module which has received 50% RDF + FYM @ 5 t ha^{-1} + biofertilizers as compared to that of organic and inorganic module. Increase in nitrogen uptake might be owing to the supply of nutrient sources to the crop.

Interaction effect between main plot cropping system and sub-plot input management modules in combination with the application of organic or inorganic fertilizer or use of integrated fertilizer were found non significant with respect to content of N in grain and straw and total uptake of N by wheat and gram respectively. Pandagre *et al.* (1992) reported that the highest nitrogen (2.132%) content in wheat grain while straw recorded (0.370%) N with the application of higher level of N_{120} P_{80}.

The total uptake of N in wheat and gram (60.89 kg ha^{-1} and 62.75 kg ha^{-1}, respectively) increases in inorganic module followed by an integrated module (58.28 kg ha^{-1} and 60.47 kg ha^{-1} in wheat and gram, respectively). Sharma and Bajpai (1989) also reported uptake of nitrogen by grain and straw of wheat significantly increased due to cultivation of Kharif legume as compared to fallow soil or cereal crop. They also reported nitrogen uptake of 91.23 and 92.75 kg ha^{-1} in grain of wheat and gram, respectively.

4.2.3 Content and uptake of phosphorus by soybean

Phosphorus is considered as a key element. It plays stupendous role in root development reproduction phase and seed development, phosphorus assimilation of crop is more at early stage of crop growth.

The results associated with the content of P of grain and straw of soybean crop and its total uptake of P by soybean crop is depicted in table 6. Phosphorous content of grain and straw of soybean plant at harvest was attained non significant with the cropping system. The total uptake of phosphorous by soybean found significant. In cropping system the highest total uptake of P (11.78 kg ha^{-1}) was found in soybean gram cropping sequences.

Table 6 : Content and uptake of Phosphorus by soybean crop as Influenced by cropping system in combination with various input management modules (after completion of 5^{th} cycle)

Treatments	Phosphorus content						Total P uptake (kg ha^{-1}) (Grain + Straw)		
	Grain (%)			Straw (%)					
Cropping system									
Soybean – wheat	0.54			0.16			9.55		
Soybean-gram	0.54			0.17			11.78		
SE (m) ±	0.004			0.003			0.221		
CD at 5%	NS			NS			0.663		
Input management modules									
Organic module (M-I)	0.50			0.16			8.67		
Inorganic module (M-II)	0.56			0.17			10.92		
Integrated module (M-III)	0.57			0.16			12.41		
SE (m) ±	0.013			0.012			0.273		
CD at 5%	0.039			NS			0.819		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.50	0.56	0.57	0.16	0.17	0.16	7.95	10.70	10.01
Soybean – gram	0.50	0.56	0.57	0.16	0.18	0.17	9.39	11.15	14.81
SE (m) ±	0.027			0.021			0.859		
CD at 5%	NS			NS			NS		

Among the input management modules the concentration of P in soybean grain differs significantly. Whereas concentration of P in straw was found statistically non significant and the similar trend was observed in the total uptake of P by soybean crop.

Maximum concentration of P of grain was recorded highest (0.57%) in an integrated module which has received 50% RDF + FYM @ 5 t ha^{-1} + biofertilizers, which was at par with inorganic module (0.56%) and organic module (0.50%) respectively. Whereas maximum concentration of P of straw was recorded highest (0.17%) under inorganic module which has recieved 100% RDF which was at par with organic and integrated module (0.16%) respectively.

The total uptake of P by soybean in an input management modules was observed higher (12.41 kg ha^{-1}) under integrated module which was significantly superior to both organic and inorganic module. This might be owing to the adequate supply of nutrient sources to the crop as well as due to solubilizing effect of phosphorous resulting in the availability of nutrients and from reduced loss of nutrients supplied through organic sources. Subba Rao *et al.* (1998) reported integrated effect of FYM and P on total uptake by soybean. They reported that integrated use of 8 t FYM along with 44 kg P ha^{-1} to soybean recorded the total uptake of P by 33.37% over application of p fertilizers along (44 kg ha^{-1}). He also reported that total phosphorous uptake by soybean increased progressively with rate of application of both FYM and phosphorus.

The Interaction effect between cropping system and input management modules with respect to content of P in grain and straw and its total uptake of P by soybean crop was found non significant.

4.2.4 Content and uptake of phosphorus by wheat and gram

The data with respect to content of P in grain and straw of wheat and gram and its total uptake by wheat and gram has been depicted in table 7.

Table 7 : Content and uptake of Phosphorus by Wheat and Gram as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Phosphorous content						Total P uptake (kg ha^{-1}) (Grain + Straw)		
	Grain(%)			Straw(%)					
Cropping system									
Soybean – wheat	0.32			0.14			14.48		
Soybean – gram	0.34			0.12			9.24		
SE (m) ±	0.003			0.005			0.348		
CD at 5%	0.009			NS			1.044		
Input management modules									
Organic module (M-I)	0.41			0.12			11.45		
Inorganic module (M-II)	0.45			0.13			12.34		
Integrated module (M-III)	0.43			0.15			11.79		
SE (m) ±	0.013			0.006			0.646		
CD at 5%	NS			NS			NS		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.30	0.33	0.33	0.13	0.14	0.15	13.55	15.17	14.72
Soybean – gram	0.53	0.57	0.54	0.11	0.13	0.12	9.35	9.51	8.85
SE (m) ±	0.014			0.012			0.700		
CD at 5%	NS			NS			NS		

Concentration of P in grain and its total uptake of P by wheat and gram were found significant where as concentration of P in straw of wheat and gram were found non significant. Conc. of P in grain was recorded highest (0.34%) under soybean-gram cropping sequence, where as conc. of P was recorded less in soybean-wheat cropping sequence .The total uptake of phosphorus was recorded highest (14.48 kg ha^{-1}) under soybean wheat cropping sequence.

In case of input management modules conc. of P in grain and straw of wheat and gram and its total uptake was found non significant. But however total uptake of P (12.34 kg ha $^{-1}$) were increased with the application of 100% RDF (inorganic module) over integrated module (11.79 kg ha $^{-1}$).

Interaction effect between cropping system and input management modules was found non significant.

Subba Rao *et al.* (1998) reported that total phosphorous uptake by wheat increased progressively with rates of application of both FYM and P. The highest uptake of P (14.38 kg ha $^{-1}$) was observed with addition of 16 t FYM and 44 kg P ha $^{-1}$.

Kanwar and Paliyal (2002) also reported that the uptake of P by chickpea (7.85 q ha $^{-1}$) was recorded maximum with the treatment 75 kg P_2O_5 ha $^{-1}$+vermicompost @ 10 t ha $^{-1}$.

4.2.5 Content and uptake of Potassium by soybean

The results associated with the concentration of K in grain and straw and its total uptake by soybean plant is depicted in table 8. Potassium concentration of grain and straw of soybean plant at harvest stage was attained non significant with the cropping system. From the data, the total uptake of potassium by soybean was found significant with cropping system.

Highest total uptake of K (40.62 kg ha $^{-1}$) by soybean was observed under soybean-gram sequence. In case of input management modules concentration of potassium in grain and straw of soybean was found non significant. Whereas uptake of potassium by soybean was found significant in respect of input management modules.

Table 8 : **Content and uptake of potassium by soybean as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)**

Treatments	Potassium Content						Total K uptake (kg ha^{-1}) (Grain + Straw)		
	Grain (%)			Straw (%)					
Cropping system									
Soybean – wheat	0.47			1.53			33.10		
Soybean – gram	0.47			1.53			40.62		
SE (m) ±	0.011			0.009			0.447		
CD at 5%	NS			NS			1.341		
Input management modules									
Organic module (M-I)	0.45			1.49			32.02		
Inorganic module (M-II)	0.48			1.58			37.68		
Integrated module (M-III)	0.49			1.54			40.88		
SE (m) ±	0.013			0.028			0.487		
CD at 5%	NS			NS			1.461		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.46	0.48	0.48	1.48	1.57	1.53	29.68	36.84	32.80
Soybean – gram	0.45	0.48	0.49	1.50	1.58	1.54	34.47	38.53	48.96
SE (m) ±	0.010			0.029			1.091		
CD at 5%	NS			NS			3.273		

Highest total uptake of K (40.88 kg ha $^{-1}$) by soybean was observed under integrated module which has received 50% RDF+FYM@ 5t ha $^{-1}$+biofertilizers than that of inorganic and organic module. Lowest total K uptake (32.02 kg ha $^{-1}$) by soybean was registered under treatment receiving FYM 5 tha $^{-1}$ alone (organic module).

Santhy *et al.* (1998) reported that application of 100% NPK along with FYM @ 10 t ha $^{-1}$ increased the uptake of potassium greatly as compared to 100 percent NPK alone.

Chaturvedi *et al.* (2005) reported that highest total uptake of K was observed with recommended NPK+FYM @ 10 t ha^{-1} which resulted in higher uptake of than recommended NPK alone. This might be owing to increased supply of nutrients to the crop, as well as due to the indirect effect resulting from reduced loss of organically supplied nutrients.

Interaction effect between cropping system and input management modules was found non significant with respect to the concentration of K in grain and straw. Whereas uptake of potassium by soybean crop was found significant . Uptake of K was recorded highest (48.96 kg ha $^{-1}$) in an integrated module under soybean- gram cropping sequence and lowest uptake of K (29.68 kg ha $^{-1}$) in an organic module under soybean-wheat cropping system.

4.2.6 Content and uptake of potassium by wheat and gram

The data in respect of content of K in grain and straw of wheat and gram and the uptake of potassium by wheat an gram are reported in table 9.

Table 9 : Content and uptake of potassium by wheat and gram as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Potassium Content						Total K uptake (kg ha^{-1}) (Grain + Straw)		
	Grain(%)			Straw (%)					
Cropping system									
Soybean – wheat	0.52			1.32			63.70		
Soybean – gram	0.41			1.24			27.98		
SE (m) ±	0.003			0.002			0.823		
CD at 5%	0.009			0.007			2.469		
Input management modules									
Organic module (M-I)	0.45			1.24			43.02		
Inorganic module (M-II)	0.48			1.29			48.20		
Integrated module (M-III)	0.48			1.31			46.30		
SE (m) ±	0.006			0.006			0.613		
CD at 5%	0.020			0.020			1.839		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.51	0.52	0.54	1.26	1.33	1.36	61.80	66.49	62.82
Soybean – gram	0.39	0.43	0.42	1.22	1.25	1.27	24.45	29.90	29.78
SE (m) ±	0.003			0.006			0.846		
CD at 5%	0.009			0.020			2.538		

Potassium concentration in grain and straw of wheat and gram at harvest stage was attained significant with cropping system. Highest potassium concentration in grain (0.52%) was obtained under soybean-wheat cropping sequence. Highest potassium concentration in straw (1.32%) was also obtained under soybean-wheat cropping sequence. Total uptake of potassium by wheat and gram also differs significantly with cropping system. Highest total uptake of potassium (63.70 kg ha $^{-1}$) was recorded under soybean-wheat cropping system.

Among the input management modules, the concentration of potassium in grain and straw of wheat and gram was recorded higher (0.48% and 1.31% respectively) under integrated module which is statistically at par with an inorganic module. The total uptake of potassium was found highest (48.20 kg ha^{-1}) in an inorganic module which has received 100% RDF than that of integrated module.

Interaction effect of cropping system and input management modules shows significant effect with respect to concentration of potassium in grain and straw of wheat and gram as well as similar trend was observed in case of total uptake of potassium by wheat and gram. Highest concentration of potassium in grain and straw of wheat and gram crop (0.54%, 1.36%, 0.42% and 1.27% respectively) was observed in an integrated module under soybean wheat cropping sequence. Lowest concentration of potassium in grain and straw of wheat and gram was observed (0.39% and 1.22%, respectively) under soybean gram sequence in an organic module. Total uptake of potassium by wheat and gram plant was recorded highest (62.82 Kg ha^{-1}) in an integrated module under soybean-wheat cropping system and lowest uptake (24.45 Kg ha^{-1}) was observed under soybean-gram sequence in an organic module.

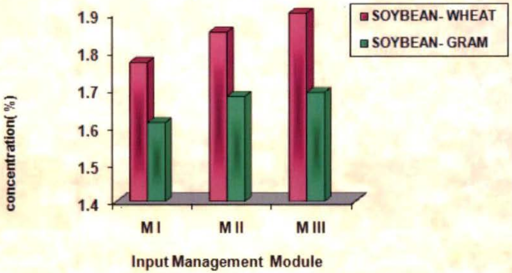


Fig (4a):Interaction between cropping system with input management module in total Potassium content at harvest of sequence crop

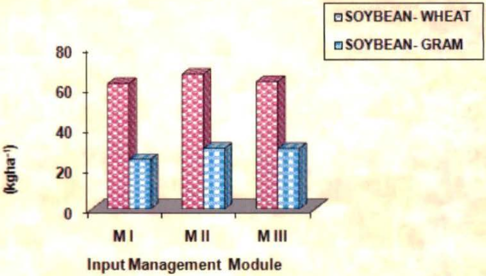


Fig (4b):Interaction between cropping system with input management module on total Potassium uptake at harvest of sequence crop

4.2.7 Content and uptake of sulphur by soybean

The data pertaining to the concentration of sulphur in grain and straw of soybean crop and its uptake by soybean crop are reported in table10.

Table 10: Content and uptake of sulphur by soybean as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Sulphur Content						Total S uptake (kg ha^{-1}) (Grain + Straw)		
	Grain(%)			Straw(%)					
Cropping system									
Soybean – wheat	0.21			0.14			5.17		
Soybean – gram	0.24			0.16			7.17		
SE (m) ±	0.001			0.001			0.086		
CD at 5%	0.004			0.004			0.258		
Input management modules									
Organic module (M-I)	0.19			0.13			4.56		
Inorganic module (M-II)	0.23			0.16			6.20		
Integrated module (M-III)	0.26			0.17			7.75		
SE (m) ±	0.001			0.001			0.096		
CD at 5%	0.003			0.003			0.288		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.17	0.22	0.25	0.11	0.15	0.17	3.63	5.79	6.09
Soybean – gram	0.21	0.25	0.26	0.15	0.16	0.18	5.50	6.61	9.41
SE (m) ±	0.002			0.001			0.142		
CD at 5%	0.006			0.003			0.426		

Concentration of sulphur in grain and straw of soybean crop differs significantly with cropping system. Similar trend was observed in uptake of sulphur by soybean crop. Highest concentration of sulphur in grain and straw (0.24% and 0.16%) respectively was observed under soybean-gram sequence. Highest total uptake of sulphur was (7.17 kg ha^{-1}) was recorded under soybean-gram sequence than that of soybean-wheat sequence.

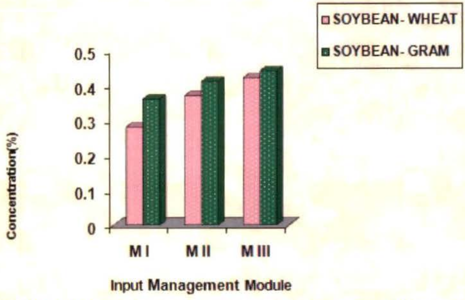


Fig (5a): Interaction between cropping system with input management module in total Sulphur content atharvest of soybean

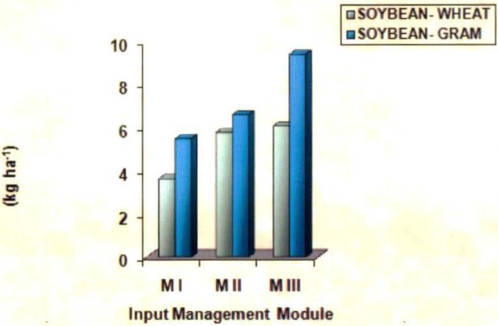


Fig (5b) :Interaction between cropping system with input management module in total Sulphur uptake at harvest of soybean

4.2.8 Content and uptake of sulphur by wheat and gram

The data related to content of sulphur in grain and straw of wheat and gram and the total uptake of sulphur by wheat and gram are reported in table 11.

Table 11 : Content and uptake of sulphur by wheat and gram as Influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Sulphur Content						Total S uptake (kg ha^{-1}) (Grain + Straw)		
	Grain(%)			Straw(%)					
Cropping system									
Soybean – wheat	0.15			0.13			8.81		
Soybean – gram	0.16			0.13			4.30		
SE (m) ±	0.001			0.001			0.064		
CD at 5%	0.003			0.003			0.192		
Input management modules									
Organic module (M-I)	0.13			0.12			5.72		
Inorganic module (M-II)	0.15			0.13			6.85		
Integrated module (M-III)	0.17			0.14			7.11		
SE (m) ±	0.001			0.001			0.068		
CD at 5%	0.003			0.003			0.204		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	0.12	0.15	0.16	0.11	0.13	0.14	7.77	9.22	9.45
Soybean – gram	0.15	0.16	0.17	0.12	0.13	0.14	3.67	4.48	4.76
SE (m) ±	0.001			0.002			0.105		
CD at 5%	0.003			0.006			0.315		

Among the cropping system the data related to the content of sulphur in Grain and straw of wheat and gram differs significantly. Similar trend was observed in case of total uptake of sulphur by wheat and gram crop. Highest conc. of sulphur in grain and straw of wheat and gram was recorded (0.16% and 0.13%) under soybean-gram cropping system which remained at par with soybean-wheat cropping system, respectively. Highest total uptake of S by wheat and gram crop (8.81 kg ha^{-1}) was observed under soybean-wheat

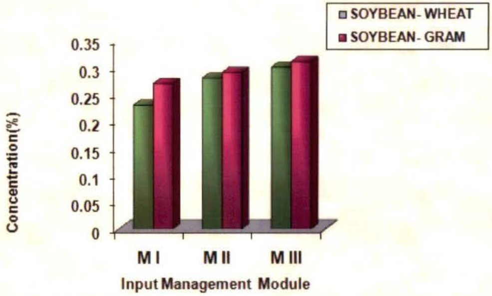


Fig (6a) :Interaction between cropping system with input management module in total Sulphur content at harvest of sequence crop

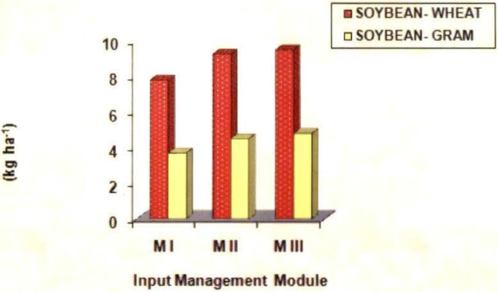


Fig (6b) :Interaction between cropping system with input management module in total Sulphur uptake at harvest of sequence crop cropping system which is significantly superior over soybean-gram cropping system.

Among the input management modules content of sluphur in grain and straw and the total uptake of sulphur by wheat and gram differs significantly. Highest concentration of sulphur in grain and straw of wheat and gram (0.17% and 0.14% respectively) was recorded in an integrated module which has received 50% RDF + FYM @ 5 t ha $^{-1}$ + bio fertilizers which remained at par with an inorganic module that had received 100%RDF. Highest uptake of sulphur by wheat and gram (7.11 kg ha $^{-1}$) was observed under integrated module.

Interaction effect between cropping system and input management modules showed significant results in case of content of sulphur in grain and straw of wheat and gram and also in total uptake of sulphur by wheat and gram respectively. The highest content of sulphur in grain and straw of wheat and gram (0.17% and 0.14%) respectively was observed in an integrated module under soybean-gram cropping sequence which remained at par with inorganic module under the same cropping sequence .Whereas, the highest uptake of sulphur by wheat and gram (0.45 kg ha $^{-1}$) was recorded under soybean-wheat cropping system under integrated module which remained at par with inorganic module under the same cropping system.

4.3 Content and uptake of micronutrients by soybean, wheat and gram

4.3.1 Content and uptake of Fe by soybean

The data regarding content of Fe in grain and straw of soybean crop and the total uptake of Fe by soybean crop are depicted in table 12.

Among the cropping system content of Fe in grain and straw and uptake of Fe by soybean crop differs significantly. The highest content of Fe in grain and straw of soybean crop (21. 8% and 20.3% respectively) was recorded under soybean-gram cropping sequence. The Highest total uptake of Fe by soybean (768.0 g ha^{-1}) was observed under soybean-gram cropping sequence respectively.

Table 12 : Content and uptake of Fe by soybean as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Fe Content						Total Fe uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw(mg kg^{-1})					
Cropping system									
Soybean – wheat	21.3			20.4			626.2		
Soybean – gram	21.8			20.3			768.0		
SE (m) ±	0.03			0.01			9.48		
CD at 5%	0.09			0.03			28.44		
Input management modules									
Organic module (M-I)	17.2			15.6			481.5		
Inorganic module (M-II)	20.3			18.8			640.8		
Integrated module (M-III)	27.2			26.6			968.9		
SE (m) ±	0.03			0.07			12.44		
CD at 5%	0.09			0.21			37.32		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	16.6	17.8	23.3	15.1	15.5	30.6	424.8	531.9	749.8
Soybean – gram	17.9	22.7	31.1	16.1	22.0	22.7	538.2	749.8	921.8
SE (m) ±	0.08			0.15			20.06		
CD at 5%	0.24			0.45			60.18		

Among the input management modules conc. of Fe in grain and straw of soybean crop and the total uptake of Fe by soybean crop was found significant. More conc. of Fe in grain and straw of soybean crop (27.2% and 26.6% respectively) under integrated module and was significantly superior over organic and inorganic module. Highest uptake of Fe was recorded

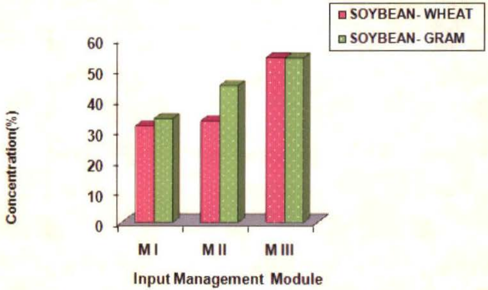
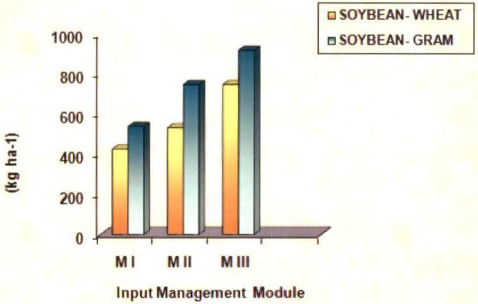


Fig (7a): interaction between cropping system with input management module in total Fe content at harvest of soybean

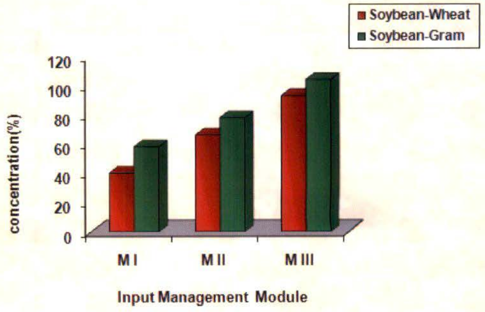


Fig(7b): Interaction between cropping system with input management module in total Fe uptake at harvest of soybean

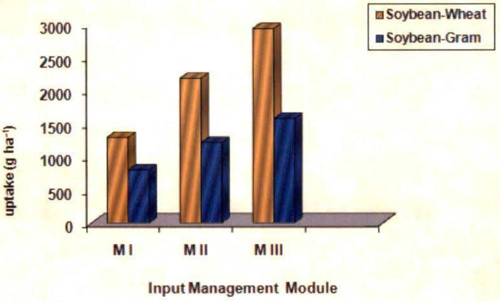
Table 15 : **Content and uptake of Mn by wheat and gram as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)**

Treatments	Mn Content						Total Mn uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw(mg kg^{-1})					
Cropping system									
Soybean – wheat	36.0			30.0			2137.0		
Soybean – gram	44.0			36.0			1198.0		
SE (m) ±	0.5			0.2			29.7		
CD at 5%	1.5			0.6			89.1		
Input management modules									
Organic module (M-I)	27.0			22.0			1045.0		
Inorganic module (M-II)	38.0			34.0			1701.0		
Integrated module (M-III)	55.0			43.0			2256.0		
SE (m) ±	0.6			0.2			21.2		
CD at 5%	1.8			0.7			63.6		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	21.0	35.0	52.0	19.0	31.0	41.0	1292.0	2188.0	2932.0
Soybean – gram	33.0	41.0	58.0	25.0	037.0	46.0	799.0	1215.0	1579.0
SE (m) ±	0.6			0.4			29.7		
CD at 5%	1.8			1.2			89.1		

Interaction effect between the main plot cropping system and sub plot input management modules revealed significant results with respect to conc. of Mn in grain and straw of wheat and gram and similar trend was found in case of uptake of Mn by wheat and gram. The highest content of Mn in grain and straw of wheat and gram was recorded (58.0 and 460.0 mg kg^{-1}) under soybean-gram cropping sequence in an integrated module whereas, lowest content of Mn in grain and straw of wheat and gram was reported (21.0 and 19.0 mg kg^{-1}) under soybean-wheat cropping sequence in an organic module. Higher uptake of Mn by wheat and gram was recorded (2932.0 g ha^{-1}) under soybean-wheat cropping sequence in an integrated module. However, the



Fig(8a) :Interaction between cropping system with input management module in total Mn content at harvest of sequence crop



Fig(8b) : Interaction between cropping system with input management module in total Mn uptake at harvest of sequence crop lowest uptake of Mn was recorded (799.0 g ha^{-1}) under soybean-gram cropping sequence in an organic module.

4.3.5 Content and uptake of Zn by soybean

The data regarding with the content of Zn in grain and straw of soybean and their total uptake by soybean crop are depicted in table 16.

With the cropping system, the results which attained at the harvest stage of soybean with respect to Zn content in grain and straw of soybean crop and their total uptake by soybean crop differs significantly. The maximum content of Zn in grain and straw of soybean was recorded (40.0 and 29.0 mg kg^{-1}) respectively under soybean-gram cropping system. Higher uptake of Zn by soybean was (1264.0 g ha^{-1}) observed under soybean gram cropping system.

Among the input management modules, the results with respect to conc. of Zn in grain and straw of soybean crop and their total uptake of Zn by soybean crop differs significantly. The highest content of Zn in grain of soybean was recorded (50.0 mg kg^{-1}) under integrated module which is significantly superior over organic and inorganic module. The highest content of Zn in straw of soybean was (33.0 mg kg^{-1}) observed under integrated module. Whereas, the total uptake of Zn by soybean crop was also recorded (1513.0 g ha^{-1}) in an integrated module which is significantly superior over organic and inorganic module.

Interaction effect between the main plot cropping system and sub plot input management modules revealed that the content of Zn in grain of soybean crop was found non significant, whereas, the content of Zn in straw of soybean crop differs significantly with respect to total uptake of Zn by soybean which was also differs significantly at the end of the 5th cycle.

Table 16: Content and uptake of Zn by soybean as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Zn Content						Total Zn uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw(mg kg^{-1})					
Cropping system									
Soybean – wheat	30.0			23.0			788.0		
Soybean – gram	40.0			29.0			1264.0		
SE (m) ±	2.0			0.4			30.4		
CD at 5%	6.0			1.2			91.2		
Input management modules									
Organic module (M-I)	24.0			17.0			592.0		
Inorganic module (M-II)	33.0			27.0			972.0		
Integrated module (M-III)	50.0			33.0			1513.0		
SE (m) ±	1.7			0.3			29.1		
CD at 5%	5.1			0.9			87.3		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	19.0	29.0	43.0	11.0	26.0	32.0	384.0	872.0	1107.0
Soybean – gram	28.0	37.0	56.0	23.0	29.0	35.0	801.0	1072.0	1919.0
SE (m) ±	4.0			0.8			70.0		
CD at 5%	NS			2.6			210.0		

The maximum content of Zn in straw of soybean was recorded (35.0 mg kg^{-1}) under soybean-gram cropping sequence in an integrated module which remained at par with soybean-wheat cropping sequence under the same module. Whereas, the lowest content of Zn in straw was recorded (11.0 mg kg^{-1}) under soybean-wheat cropping sequence in an organic module. Higher uptake of Zn by soybean crop was (1919.0 g ha^{-1}) observed under soybean- gram cropping sequence in an integrated module, which is significantly superior over organic and inorganic module in both the cropping system. The lower uptake of Zn by soybean crop was (384.0 g ha^{-1}) registered under soybean-wheat sequence in an organic module.

4.3.6 Content and uptake of Zn by wheat and gram

The data pertaining with the content of Zn in grain and straw of wheat and gram and their total uptake of Zn by wheat and gram are reported in table 17.

Among the cropping system, the results which attained at the harvest of wheat and gram was found significant with respect to Zn content in grain and straw of wheat and gram and their total uptake of Zn by wheat and gram. The highest content of Zn in grain and straw of wheat and gram was (40.0 and 33.0 mg kg^{-1}) under soybean-gram cropping system and is significantly superior over soybean-wheat cropping system. Higher uptake of Zn by wheat and gram was (1802.0 g ha^{-1}) recorded under soybean-wheat cropping system.

Among the input management modules after the completion of 5^{th} cycle the results revealed that the content of Zn in grain and straw of wheat and gram differs significantly. Similar trend was observed in case of uptake of Zn by wheat and gram. The highest content of Zn in grain and straw of wheat and gram was recorded (45.0 and 38.0 mg kg^{-1}) respectively in an integrated module which was significantly superior over organic and inorganic module. Whereas, the highest uptake of Zn by wheat and gram was recorded (1873.0 g ha^{-1}) in an integrated module which is significantly superior over organic and inorganic modules.

Interaction effect between main plot cropping system and subplot input management module was found significant with respect to content of Zn in grain and straw of wheat and gram and their total uptake by wheat and gram. Higher content of Zn in grain and straw of wheat and gram was (50.0 and 42.0 mg kg^{-1}) under soybean-gram cropping system in an integrated module.

Table 17 : **Content and uptake of Zn by wheat and gram as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)**

Treatments	Zn content						Total Zn uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw(mg kg^{-1})					
Cropping system									
Soybean – wheat	31.0			25.0			1802.0		
Soybean – gram	40.0			33.0			1092.0		
SE (m) ±	0.4			0.3			14.9		
CD at 5%	1.2			0.9			44.7		
Input management modules									
Organic module (M-I)	26.0			17.0			869.0		
Inorganic module (M-II)	36.0			31.0			1599.0		
Integrated module (M-III)	45.0			38.0			1873.0		
SE (m) ±	0.6			0.5			24.9		
CD at 5%	1.8			1.5			74.7		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	30.0	34.0	40.0	12.0	29.0	34.0	981.0	2084.0	2341.0
Soybean – gram	33.0	38.0	50.0	23.0	34.0	42.0	756.0	1114.0	1405.0
SE (m) ±	1.0			0.4			12.2		
CD at 5%	3.0			1.2			36.6		

Lowest content of Zn in grain and straw of wheat and gram was registered (30.0 and 12.0 mg kg^{-1}) under soybean-wheat cropping sequence in an organic module. Higher uptake of Zn by wheat and gram was (2341.0 g ha^{-1}) observed under soybean-wheat cropping system in an integrated module. However, lower uptake of Zn by wheat and gram was recorded (756.0 g ha^{-1}) under soybean-gram cropping sequence in an organic module.

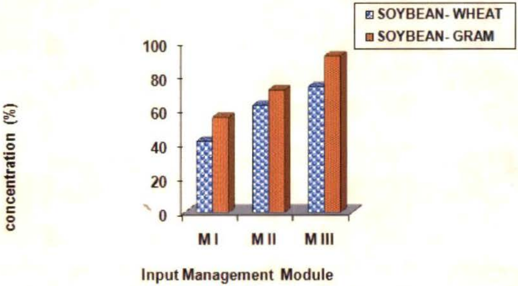


Fig (9a):Interaction between cropping system with input management modules in total Zn content at harvest of sequence crop

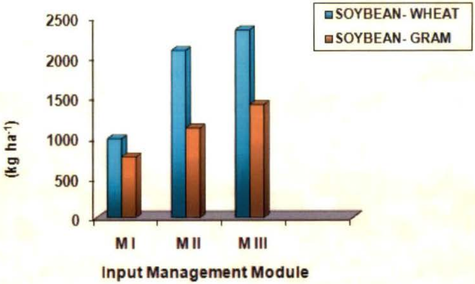


Fig (9 b): Interaction between cropping system with input management module in total Zn uptake at harvest of sequence crop

4.3.7 Content and uptake of Cu by soybean

The data pertaining to content of Cu in grain and straw of soybean crop and the total uptake of Cu by soybean crop are reported in table 18.

Table 18: Content and uptake of Cu by soybean as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Cu Content						Total Cu uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw(mg kg^{-1})					
Cropping system									
Soybean – wheat	3.0			2.1			74.6		
Soybean – gram	3.4			2.7			112.8		
SE (m) ±	0.05			0.04			1.56		
CD at 5%	0.15			0.12			4.68		
Input management modules									
Organic module (M-I)	2.1			1.4			50.9		
Inorganic module (M-II)	3.4			2.4			92.8		
Integrated module (M-III)	4.1			3.4			137.3		
SE (m) ±	0.05			0.03			1.37		
CD at 5%	0.15			0.09			4.11		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	1.8	3.3	4.0	1.0	2.1	3.2	35.1	83.8	104.8
Soybean – gram	2.4	3.5	4.5	1.9	2.6	3.6	66.7	101.8	169.9
SE (m) ±	0.08			0.04			1.63		
CD at 5%	0.24			0.12			4.89		

After completion of 5th cycle cropping system shows significant results with respect to conc. of Cu in grain and straw of soybean crop and also similar trend was observed in case of total Cu uptake by soybean crop. The highest conc. of Cu in grain and straw was recorded (3.4% and 2.7%) in soybean-gram cropping system. Whereas, higher total uptake of Cu by soybean crop was (112.8 g ha^{-1}) observed under soybean-gram cropping system.

Among the input management module the content of Cu in grain and straw of soybean crop was found significant. The total uptake of Cu by soybean crop was also found significant. The higher conc. of Cu in grain and

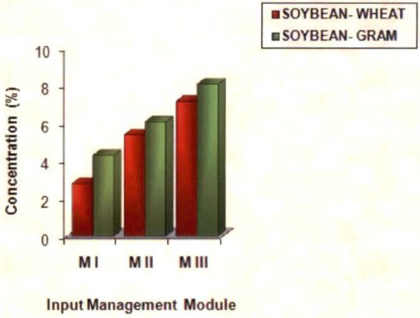
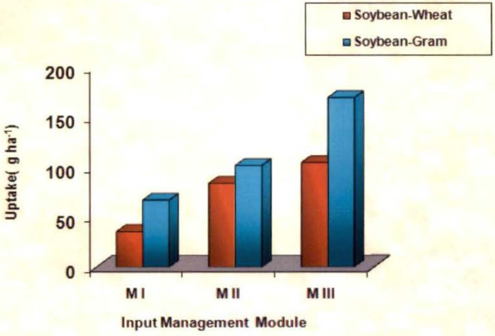


Fig (10a) :Interaction between cropping system with input management module in total Cu content at harvest of soybean



Fig(10b): Interaction between cropping system with input management module in total Cu uptake at harvest of soybean straw of soybean was (4.1% and 3.4%, respectively) observed in an integrated module which was at par with an inorganic module (3.4% and 2.4%, respectively) and was significantly superior over organic module. The highest uptake of Cu by soybean crop was (137.3 g ha^{-1}) observed in an integrated module. This might be owing to the nutrient sources added to the soil.

Interaction effect between main plot cropping system and subplot input management modules was found significant with respect to content of Cu in grain and straw and also with the total uptake of Cu in soybean crop. The higher content of Cu in grain and straw of soybean crop was (4.5 mg kg^{-1} and 3.6 mg kg^{-1}, respectively) observed under soybean-gram cropping sequence in an integrated module. Whereas, the lowest conc. of Cu in grain and straw was observed (1.8 mg kg^{-1} and 1.0 mg kg^{-1}, respectively) under soybean wheat cropping system in an organic module. The higher uptake of Cu by (169.9 g ha^{-1}) soybean-gram cropping system was recorded in an integrated module. The lowest uptake of Cu was observed (35.1 g ha^{-1}) under soybean-wheat cropping system was recorded in an organic module.

4.3.8 Content and uptake of Cu by wheat and gram

The data regarding content of Cu in grain and straw of wheat and gram and the total uptake of Cu by wheat and gram are reported in table 19.

It is explicate from the data that the conc. of Cu in grain and straw of wheat and gram and the total uptake of Cu by wheat and gram were found significant. The maximum Cu content in grain and straw of wheat and gram was (4.0 mg kg^{-1} and 2.6 mg kg^{-1}) observed under soybean-gram cropping sequence which remained at par with soybean-wheat cropping sequence. The highest total uptake of Cu by wheat and gram was (184.6 g ha^{-1}) observed under soybean-wheat cropping system and is significantly superior over soybean-gram cropping sequence.

Table 19 : Content and uptake of Cu by wheat and gram as influenced by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Cu Content						Total Cu uptake (g ha^{-1}) (Grain + Straw)		
	Grain(mg kg^{-1})			Straw (mg kg^{-1})					
Cropping system									
Soybean – wheat	3.5			2.3			184.6		
Soybean – gram	4.0			2.6			99.8		
SE (m) ±	0.02			0.03			4.66		
CD at 5%	0.06			0.09			13.98		
Input management modules									
Organic module (M-I)	2.5			2.0			106.5		
Inorganic module (M-II)	3.5			2.5			137.7		
Integrated module (M-III)	5.1			3.0			182.4		
SE (m) ±	0.05			0.06			2.75		
CD at 5%	0.15			0.20			8.25		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	2.6	2.9	5.0	1.8	2.3	2.8	140.8	173.3	239.9
Soybean – gram	2.5	4.1	5.3	2.1	2.6	3.2	72.3	102.1	124.9
SE (m) ±	0.09			0.07			4.66		
CD at 5%	0.30			NS			13.98		

Among the input management module, the results with respect to conc. of Cu and uptake by wheat and gram were found significant. The highest conc. of Cu in grain and straw of wheat and gram was (5.0 mg kg^{-1} and 3.0 g kg^{-1}) respectively observed under integrated module. Whereas, highest uptake of Cu by wheat and gram was (182.4 g ha^{-1}) respectively observed under integrated module and is significantly superior over organic and inorganic modules.

Interaction effect between the main plot cropping system and sub plot input management module with respect to conc. of Cu in grain of wheat and gram was found significant. However the conc. of Cu in straw of wheat and gram was found non significant. Further the uptake of Cu by wheat and gram was found significant. The highest conc. of Cu in grain was (5.3 mg kg^{-1}) in soybean-gram cropping sequence under integrated module, whereas lowest conc. of Cu was noted (2.5 mg kg^{-1}) under soybean-gram cropping sequence in an organic module. In case of uptake of Cu by wheat and gram, the higher uptake was (239.9 g ha^{-1}) observed under soybean-wheat cropping system in an integrated module. However, the lowest uptake of Cu was observed (72.3 g ha^{-1}) under soybean-gram cropping sequence in an organic module.

4.4 Availability of major nutrients after harvest of kharif and rabi crops

4.4.1 Available N, P and K status of soil at harvest of soybean

The data related to available N, P and K status of soil after harvest of soybean are shown in table 20. Results indicated that the status of available N, P and K were found significant due to various cropping system. Highest available N (341.88 kg ha^{-1}) and K (430.73 kg ha^{-1}) was registered in soybean - gram cropping system where as available P (30.10 kg ha^{-1}) was found to be highest in soybean-wheat cropping system. Application of inorganic fertilizers along with organic and bio-fertilizers to succeeding gram crop produced of previously crop augmented the available N and K status of soil at the completion of 5^{th} cycle of soybean under soybean - gram cropping system.

With the application of various input management modules, the available N, P and K status of soil was increased significantly. The higher available N (353.72 kg ha^{-1}), P (31.57 kg ha^{-1}) and K (453.18 kg ha^{-1}) status of soil was recorded by the conjunctive use of 50% RDF + FYM @ 5 t ha^{-1} (integrated module). The results clearly indicated the benefits of available N, P and K from the integrated module consisting the use of inorganic, organic and use of bio-fertilizers.

Table 20 : Available N, P and K status of soil at harvest of soybean as affected by cropping system in combination with various input management modules

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Cropping system									
Soybean – wheat	340.88			30.10			415.65		
Soybean – gram	341.88			28.89			430.73		
SE (m) ±	0.319			0.102			0.555		
CD at 5%	0.957			0.306			1.665		
Input management modules									
Organic module (M-I)	335.64			28.25			390.52		
Inorganic module (M-II)	334.78			28.66			425.88		
Integrated module (M-III)	353.72			31.57			453.18		
SE (m) ±	0.470			0.110			0.973		
CD at 5%	1.410			0.33			2.919		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	343.50	330.55	351.59	28.79	29.09	32.47	389.74	413.14	444.08
Soybean – gram	327.78	339.00	355.85	22.72	28.24	30.72	391.40	438.62	462.28
SE (m) ±	2.472			0.471			3.609		
CD at 5%	2.852			NS			4.164		

The interaction between cropping system and various input management modules represents significant effect with respect to available N and K status of soil, while the available P was found statistically non-significant. The available N status of soil was recorded (355.85 kg ha^{-1}) under soybean-gram cropping system in an integrated module which remains statistically at par in soybean - wheat cropping system (351.59 kg ha^{-1}) under the same module. The lowest value of available N status of soil (327.78 kg ha^{-1}) was registered in organic module under soybean-gram cropping sequence. The available K status of soil (462.28 kg ha^{-1}) under soybean-gram cropping system, in an integrated module which remains statistically at par with soybean-wheat cropping system (444.08 kg ha^{-1}) under the same module. Whereas, the Lowest value of available K (389.74 kg ha^{-1}) was recorded under soybean-wheat cropping system in an organic module. This clearly shows, that continuous inclusion of leguminous residues along with fertilizer registered more available N status in soil than the inorganic treatment.

Sharma *et al.* (1986) reported that the available N in soil after completion of 2nd cycle increased after rabi legumes (pea, chickpea) and kharif legumes (greengram and blackgram) as compared with those under their respective cereal crops in rabi, wheat and in kharif, sorghum and fallow.

4.4.2 Available N, P and K status of soil at harvest of wheat and gram

The data pertaining to available N, P and K status of soil are presented in table 21. After completion of 5th cycle of cropping system, the status of available N, P and K of soil were found significantly higher when gram succeeded after soybean followed by soybean-wheat, might be due to inclusion of nitrogenous fertilizer in adequate amount through inorganic and more quantity of residues added in the soil. The status of available P of soil was found significant by growing wheat and gram after soybean. Comprising the cropping system, the highest available N of soil (355.36 kg ha^{-1}) and available K of soil (423.66 kg ha^{-1}) was obtained under soybean-gram system which might be due to inclusion of major nutrients in adequate amount through inorganic source and adequate quantity residues added by soybean and gram crop.

The higher available P of soil (36.20 kg ha^{-1}) was obtained under soybean- wheat cropping system.

The data in table 21 depicted that there was significant increase in available N, P and K status of soil with the application of organic, inorganic or in combination of organic and inorganic and integrated modules. With the application 50% RDF - FYM 5 t ha^{-1} (integrated module), the mean value of available N, P and K status of soil were found significantly superior over organic and inorganic modules. However, the mean value of available K status of soil found statistically at par with application of organic and inorganic module.

Table 21 : Available N, P and K status of soil at harvest of wheat and gram as affected by cropping system in combination with various management modules (after completion of 5th cycle)

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Cropping system									
Soybean – wheat	341.25			36.20			419.31		
Soybean – gram	355.36			34.84			423.66		
SE (m) ±	0.288			0.063			0.691		
CD at 5%	0.864			0.189			2.073		
Input management modules									
Organic module (M-I)	344.65			32.53			415.40		
Inorganic module (M-II)	340.14			35.97			423.71		
Integrated module (M-III)	360.11			38.05			425.36		
SE (m) ±	0.165			0.104			0.824		
CD at 5%	0.495			0.312			2.472		
Interaction (Cropping system x modules)									
	M - I	M – II	M - III	M - I	M – II	M - III	M - I	M – II	M - III
Soybean – wheat	337.56	334.30	351.88	32.44	36.39	39.77	412.54	421.26	424.14
Soybean – gram	351.75	345.99	368.35	32.63	35.55	36.34	418.26	426.16	426.58
SE (m) ±	0.474			0.129			1.300		
CD at 5%	1.422			0.387			NS		

The interaction effects between cropping system and various input management module was found significant with respect to available N and P status of soil whereas K status of soil was found statistically non-significant. Available N status of soil was obtained highest with integrated modules (368.35 kg ha^{-1}) under soybean-gram cropping sequence. While the value of available P (39.77 kg ha^{-1}) were observed higher under soybean-gram cropping sequence. Further data reported that available K status of soil was found at par with the 100% inorganic fertilizer (426.16 kg ha^{-1}) under the same cropping system but the effect of this treatment combination found non-significant.

Babhulkar *et al.* (2000) reported that among the cropping sequence of soybean-wheat , soybean-gram and soybean-mustard, soybean followed by gram was superior over the sequence with respect to organic carbon, available P and available K based on 5 years study under these sequence.

4.4.3 Available sulphur, calcium and magnesium status of soil at harvest of soybean

The data related to available S, exchangeable Ca^{++} and Mg^{++} status of soil after harvest of soybean are presented in table 22. Results indicated that the status of available S and exchangeable Mg^{++} were found significant while the status of exchangeable Ca^{++} were found non-significant, as influenced due to various cropping system. Highest available S (17.21 kg ha^{-1}) was observed in soybean-gram cropping system, whereas exchangeable Ca^{++} (51.57 c mol (p^{+}) kg^{-1}) and Mg^{++} (27.13 c mol (p^{+}) kg^{-1}) was observed in soybean-gram cropping system.

With the application of various input management modules the mean value of available S and exchangeable Ca^{++} and Mg^{++} status of soil was increase significantly. The higher mean available S (18.18 kg ha^{-1}), exchangeable Ca^{++} (54.65 c mol (p^{+}) kg^{-1}) and exchangeable Mg^{++} (27.65 c mol (p+) kg^{-1}) status of soil were recorded by the conjunctive use of 50% RDF + FYM @ 5 t ha^{-1} (integrated module). This clearly indicates the benefits of available S, exchangeable Ca^{++} and Mg^{++} organic and use of bio-fertilizers. The interaction effect between cropping system and various input management represents significant with respect to available S and exchangeable Mg^{++} status of soil, whereas exchangeable Ca^{++} was found statistically non-significant. The available S status of 50% RDF coupled with FYM @ 5 t ha^{-1} + bio-fertilizers (integrated module) under soybean-gram cropping system which remained statistically at par in soybean-wheat cropping sequence (18.03 kg ha^{-1}) under the same module. Exchangeable Mg^{++} status of soil was recorded higher (32.50 c mol (p^{+}) kg^{-1}) in an integrated module under soybean-gram cropping system which remained statistically significant over soybean-wheat cropping sequence (22.80 c mol (p^{+}) kg^{-1}) under the same module.

Table 22 : **Available Sulphur, Exchangeable Calcium and Magnesium status of soil after harvest of soybean as influenced by cropping system in combination with various management modules (after completion of 5th cycle)**

Treatments	Available S (kg ha^{-1})			Exchangeable Ca^{++} (cmol(p+)kg^{-1})			Exchangeable Mg^{++}(cmol(p+)kg^{-1})		
Cropping system									
Soybean – wheat	16.74			50.80			21.50		
Soybean – gram	17.21			51.57			27.13		
SE (m) ±	0.006			0.574			0.855		
CD at 5%	0.018			NS			2.565		
Input management modules									
Organic module (M-I)	17.16			51.95			23.75		
Inorganic module (M-II)	15.58			46.95			21.55		
Integrated module M-III)	18.18			54.65			27.65		
SE (m) ±	0.009			0.652			0.776		
CD at 5%	0.027			1.956			2.328		
Interaction (Cropping system x modules)									
	M - I	**M - II**	**M - III**	**M - I**	**M - II**	**M - III**	**M - I**	**M - II**	**M - III**
Soybean – wheat	17.10	15.10	18.03	51.00	45.20	53.10	25.30	17.80	22.80
Soybean – gram	17.22	16.07	18.33	52.90	48.70	56.20	23.90	23.60	32.50
SE (m) ±	0.010			1.535			1.165		
CD at 5%	0.035			NS			3.495		

The interaction effect between cropping system and various management modules in respect of available sulphur was found to be significant. The use of organic and bio-fertilizer is king pin of strategy for achieving the queen objective of enhanced productivity and assure soil fertility. The lowest value of available S in soil (15.10 kg ha^{-1}) was obtained in inorganic module (100% RDF) under soybean-wheat cropping sequence. Data further revealed that when application of inorganic fertilizer alone recorded the available S status of soil (16.07 kg ha^{-1}) and it was found at par with the use of organic along with bio-fertilizers under soybean-gram cropping system. Whereas, the lowest value of exchangeable Mg^{++} in soil (17.80 cmol (p+) kg^{-1}) was found in inorganic module under soybean-wheat cropping sequence. Thakur and Sawarkar (2009) reported that maximum build up of S was recorded in plots that have received 100% NPK + FYM.

Babhulkar *et.al* (2000) reported that CEC of soil was found to be significantly increased by the conjunctive use of organic and inorganic fertilizers.

Biswas *et al.* (1967) reported that increase in CEC was associated with rise in organic matter content.

The exchangeable Ca^{++} of soil was found non-significant with interaction effect between cropping system and modules.

4.4.4 Available sulphur, calcium and magnesium status of soil at harvest of wheat and gram

The data pertaining to available S and exchangeable Ca^{++} and Mg^{++} status of soil is presented in table 23. After completion of 5th cycle of cropping systems, the status of available S and exchangeable Ca^{++} were found significantly higher when gram succeeded after soybean followed by soybean-wheat might be due to more quantity of residues added in the soil. The status of exchangeable Mg^{++} was found non-significant by growing wheat and gram after soybean. Comprising the cropping system, the highest available S of soil (17.50 kg ha^{-1}) and exchangeable Ca^{++} of soil (57.50 (cmol (p^+) kg^{-1}) was obtained under soybean-gram system might be due to adequate quantity of residues added by soybean and gram crop.

The mean value of available S, exchangeable Ca^{++} and Mg^{++} status of soil were significantly increased with the application of organic, inorganic or in combination of organic, inorganic and integrated modules. The mean value of available S status of soil was statistically at par with application of organic and inorganic module. While exchangeable Ca^{++} and Mg^{++} status of soil were found significantly superior over organic and inorganic modules.

Table 23 : Available Sulphur, Exchangeable Calcium and Magnesium status of soil after harvest of wheat and gram as influenced by cropping system in combination with various management modules (after completion of 5th cycle)

Treatments	Available S ($kg\ ha^{-1}$)			Exchangeable Ca^{++} ($cmol(p+)kg^{-1}$)			Exchangeable Mg^{++}($cmol(p+)kg^{-1}$)		
Cropping system									
Soybean – wheat	17.12			53.10			17.90		
Soybean – gram	17.50			57.50			20.97		
SE (m) ±	0.003			0.234			0.851		
CD at 5%	0.009			0.702			NS		
Input management modules									
Organic module (M-I)	17.39			54.80			19.55		
Inorganic module (M-II)	16.26			48.25			15.00		
Integrated module (M-III)	18.26			62.85			23.75		
SE (m) ±	0.003			0.869			0.470		
CD at 5%	0.009			2.607			1.141		
Interaction (Cropping system x modules)									
	M - I	**M - II**	**M - III**	**M - I**	**M - II**	**M - III**	**M - I**	**M - II**	**M - III**
Soybean – wheat	17.22	16.02	18.11	52.60	45.80	60.90	15.70	14.00	23.50
Soybean – gram	17.57	16.51	18.42	57.00	50.70	64.80	23.40	16.00	24.00
SE (m) ±	0.004			0.635			1.599		
CD at 5%	0.013			NS			NS		

The interaction effects between cropping system and various input management modules was found significant with respect to available S while exchangeable Ca^{++} and Mg^{++} were found statistically non-significant. Available S status of soil was obtained highest with integrated modules (18.42 $kg\ ha^{-1}$) under soybean-gram sequence crop while the value of exchangeable Ca^{++} (64.80 (cmol (p^{+}) kg^{-1}) and Mg^{++} (24.00 (cmol (p^{+}) kg^{-1}) were also observed higher under soybean gram sequence.

Data further revealed that the available S status of soil recorded with the application of organic fertilizers alone was 17.57 $kg\ ha^{-1}$ and it was at par with the application of 100% inorganic fertilizer (16.51 kg ha^{-1}) under the same cropping system but the effect of this treatment combination was found non-significant.

Babhulkar *et al.* (2000) reported that among the cropping sequence of soybean-wheat, soybean-gram and soybean-mustard, soybean followed by gram was found superior over other sequence with respect to available S and exchangeable Ca^{++} and Mg^{++} based on 5 years study under this sequence.

4.5 Availability of micronutrients after harvest of kharif and rabi crops

4.5.1 Micronutrient status of soil at harvest of soybean

The data related to DTPA micronutrient status of soil after harvest of soybean are shown in table 24. Results indicated that the status of DTPA - Cu and Zn were found significant while the status of Fe and Mn shows non-significantly affected due to various cropping system. The highest DTPA Cu (4.77 mg kg^{-1}) and Zn (5.20 mg kg^{-1}), Mn (8.98 mg kg^{-1}) was observed in soybean-gram cropping system whereas DTPA - Fe (7.55 mg kg^{-1}) was observed in soybean-wheat cropping system. Application inorganic fertilizers along with organic and bio-fertilizers to succeeding gram crop residues produced of previously crop augmented the DTPA - Cu, Zn and Mn status of soil at the completion of 5th cycle of soybean and under soybean-gram cropping system.

With the application of various input management modules, the mean value of DTPA - Fe, Mn and Zn status of soil was increased significantly whereas DTPA - Cu was found non-significant. The higher mean available Fe (8.35 kg kg-1), Mn (9.92 mg kg^{-1}) and Zn (5.39 mg kg^{-1}) status of soil were recorded by the conjunctive use of 50% RDF + FYM @ 5 t ha^{-1} (integrated module). The interaction effect between cropping system and various input management modules represent significant with respect to DTPA - Cu status which was recorded higher (6.90 mg kg^{-1}) with the application of 50% RDF coupled with FYM @ 5t ha^{-1} bio-fertilizer (integrated module) under soybean-gram cropping system which remained statistically and significantly superior over soybean-wheat cropping sequence (4.49 mg kg^{-1}) under the same module.

From the data, depicted in table 24, the lowest value of DTPA - Cu in soil (3.17 mg kg^{-1}) was obtained in inorganic module (100% RDF) under soybean-wheat cropping sequence.

Data further revealed that the application of inorganic fertilizer alone recorded the DTPA - Cu status of soil (3.79 mg kg^{-1}) under soybean-gram cropping sequence. This clearly shows that inclusion of leguminous residues registered more DTPA - Cu status in soil than the inorganic treatment.

Table 24 : Micronutrient status of soil (mg kg^{-1}) after harvest of soybean as affected by cropping system in combination with various input management modules (after completion of 5th cycle)

Treatments	Fe			Mn			Zn			Cu		
Cropping system												
Soybean – wheat	7.55			7.81			2.59			4.23		
Soybean – gram	6.84			8.98			5.20			4.77		
SE (m) ±	0.305			0.366			0.468			0.325		
CD at 5%	NS			NS			1.404			0.975		
Input management modules												
Organic module (M-I)	6.96			8.17			3.59			4.33		
Inorganic module (M-II)	6.26			7.10			2.70			3.48		
Integrated module (M-III)	8.35			9.92			5.39			5.69		
SE (m) ±	0.155			0.378			0.404			0.440		
CD at 5%	0.465			1.134			1.212			NS		
Interaction (Cropping system x modules)												
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M - II	M - III
Soybean – wheat	7.00	6.56	9.09	7.09	6.40	9.94	2.17	1.73	3.32	4.24	3.17	4.49
Soybean – gram	6.92	5.97	7.62	9.25	7.80	9.90	4.47	3.68	7.47	4.43	3.79	6.90
SE (m) ±	0.302			0.793			0.518			0.517		
CD at 5%	NS			NS			NS			1.551		

Kumar *et al.* (2007) reported that the rate of depletion of DTPA extractable Fe, Mn, Zn and Cu was more in 100% chemical fertilizers treated plots as compared to their combined use with organic N sources. Chelating action of organic compounds released during decomposition of organic manures increased the availability of micronutrient cations also prevented their fixation, precipitation, oxidation and leaching. The DTPA - Fe, Mn and Zn status of soil found non-significant with interaction effect between cropping system and modules.

4.5.2 Micronutrient status of soil at harvest of wheat and gram

The data in respect to DTPA - extractable - Fe, Mn, Zn and Cu status of soil is depicted in table 25. After completion of 5^{th} cycle of cropping systems, the status of DTPA - Zn of soil was found significantly higher when gram succeeded after soybean followed by soybean-wheat might be due to the addition of residues in the soil. The status of DTPA - Fe, Mn and Cu were found non-significant by growing wheat and gram after soybean. Comprising the cropping systems the highest DTPA - Zn of soil (6.14 mg kg^{-1}) was obtained under soybean-gram system might be due to adequate quantity of residues added by soybean and gram crop.

The mean value of DTPA - Fe, Mn, Zn, and Cu status of soil were found significantly superior over organic and inorganic modules. However, the mean value of DTPA - Fe, and Cu status of soil was found statistically at par with the application of organic and inorganic module.

The interaction effects between cropping system and various input management modules were found statistically non-significant with respect to DTPA - Fe, Mn, Zn and Cu status of soil DTPA - Cu, Fe and Zn status of soil was obtained highest with integrated modules (5.05 mg kg^{-1}), (9.31 mg kg^{-1}) and (6.14 mg kg^{-1}) under soybean-gram cropping sequence respectively. While the value of DTPA - Mn (23.12 mg kg^{-1}) were observed higher under soybean-wheat cropping sequence.

4.6 Chemical properties of soil at harvest of soybean, wheat and gram

4.6.1 Chemical properties of soil at harvest of soybean

The data presented in table 26 revealed that, the pH of soil was found significant by growing soybean-wheat and soybean-gram cropping system, whereas the EC and organic carbon of soil was found non-significant with cropping system. The higher pH was observed (7.63) under soybean-gram cropping system. With respect to input management module the pH of soil and organic carbon was found significant. Highest value of pH was observed (7.64) in an inorganic module which remains at par with integrated module and significantly superior over organic module. The organic carbon content of soil (7.69 g kg^{-1}) was observed with the application of 50% RDF + FYM @ 5 t ha^{-1} (Integrated module) which was significantly higher than inorganic and organic module after the completion of 5th cycle of soybean crop. This could be attributed to the addition of organic fertilizers which helps to stimulate the better root growth and more plant residues added after harvest of crop. This effect is further enhanced by addition of N and P to soybean resulting in the improvement in root and shoot growth.

Table 26 : Chemical properties of soil at harvest of soybean as influenced by cropping system with input management modules.

Treatments	pH			EC (dSm^{-1})			Organic Carbon ($g\ kg^{-1}$)		
Cropping System									
Soybean – wheat	7.58			0.25			7.56		
Soybean – gram	7.63			0.24			7.42		
SE (m) ±	0.011			0.006			0.032		
CD at 5%	0.053			NS			NS		
Input management module									
Organic module (M-I)	7.56			0.24			7.44		
Inorganic module(M-II)	7.64			0.24			7.34		
Integrated module(M-III)	7.62			0.24			7.69		
SE (m) ±	0.007			0.007			0.034		
CD at 5%	0.025			NS			0.119		
Interaction (Cropping system x modules)									
	M - I	M – II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	7.58	7.59	7.56	0.25	0.25	0.24	7.63	7.55	7.65
Soybean – gram	7.54	7.68	7.68	0.24	0.24	0.23	7.25	7.28	7.83
SE (m) ±	0.019			0.014			0.027		
CD at 5%	0.057			NS			0. 094		

The lowest organic carbon content (7.34 g kg^{-1}) was observed with the application of 100% RDF (inorganic module). The results of the present investigation are corroborating with the findings of Babhulkar *et al.* (2000), who reported that the organic carbon content of soil (6.2 g ha^{-1}) increased slightly with the application of FYM @ 7.5 ha^{-1} along with half dose of N and P to soybean over the RDF (5.3 g kg^{-1}) at the completion of five years soybean based cropping system.

Interaction effect between cropping system and input management module on pH and organic carbon content of soil was found significant whereas EC of soil was found non significant.

4.6.2 Chemical properties of soil at harvest of wheat and gram

After completion of 5th cycle of cropping system, the changes in chemical properties of soil are presented in table 27.

Table 27: Chemical properties of soil at harvest of wheat and gram as influenced by cropping system with input management modules.

Treatments	pH			EC (dSm^{-1})			Organic Carbon ($g\ kg^{-1}$)		
Cropping System									
Soybean – wheat	7.61			0.25			7.78		
Soybean – gram	7.65			0.25			7.80		
SE (m) ±	0.011			0.001			0.007		
CD at 5%	NS			NS			NS		
Input management module									
Organic module (M-I)	7.61			0.25			7.82		
Inorganic module(M-II)	7.61			0.25			7.70		
Integrated module(M-III)	7.65			0.25			7.85		
SE (m) ±	0.011			0.001			0.011		
CD at 5%	NS			NS			0.033		
Interaction (Cropping system x modules)									
	M - I	M - II	M - III	M - I	M - II	M - III	M - I	M – II	M - III
Soybean – wheat	7.62	7.61	7.60	0.25	0.25	0.25	7.79	7.73	7.83
Soybean – gram	7.61	7.62	7.71	0.25	0.25	0.25	7.84	7.80	7.96
SE (m) ±	0.023			0.003			0.020		
CD at 5%	0.069			NS			0.060		

Results revealed that the range of organic carbon content of soil 7.78 to 7.80 g kg^{-1} was recorded under two cropping system. The value of pH and EC was found non-significant under various input management modules. However, the content of organic carbon of soil was found significantly superior with the application of integrated module (50% RDF + FYM @ 5 t ha^{-1}) over rest of input management modules. The range of organic carbon content of soil shows 7.70 to 7.85 g kg^{-1} which represent moderately high. This could be attributed to inclusion of organic material, more plant residues of preceding crop and indirect influence on the chemical properties of soils.

The interaction effect between main plot cropping system and sub plot represents input management module on chemical properties of soil was found significant with respect to pH and organic content of soil. Sharma *et al.* (1986) also reported that organic carbon content of soil increased slightly due to cultivation of leguminous crop (0.41%) as compared with soil under cereal (0.38%) and fallow (0.36%).

4.7 Balance sheet of nutrients

Table 28: Balance sheet of nutrients after harvest of soybean

The data related to balance sheet of nutrients after harvest of soybean has been depicted in table 28.

Cropping sequence	Initial available nutrients+addition through fertilizers (A)	Nutrients removed by crops (kg ha^{-1}) (B)	Nutrients in balance (expected value) (kg ha^{-1}) (A-B)=X	Final available nutrients (kg ha^{-1}) (C)	Actual change of nutrients fixed balance in soil(-) or gain(+) (kg ha^{-1}) (C-X)	Average (kg $ha^{-1}yr^{-1}$)
Nitrogen						
Soybean-Wheat	327.98	101.18	226.8	340.88	+114.08	+114.08
Soybean-gram	332.79	124.70	208.09	341.88	+133.79	+133.79
Phosphorous						
Soybean-Wheat	30.35	9.55	20.8	30.10	+9.3	+9.3
Soybean-gram	29.41	11.78	17.63	28.89	+11.26	+11.26
Potassium						
Soybean-Wheat	418.53	33.10	385.43	415.65	+30.22	+30.22
Soybean-gram	426.00	40.62	385.38	430.73	+45.35	+45.35

From the above data results revealed that on the basis of individual crop legumes either soybean or gram removed significantly. Higher quantity of nitrogen (124.70 kg ha^{-1}) at harvest of soybean. This is due to the fact that fixation and self utilization of the atmospheric nitrogen and the transformation of the same in proteinaceous grains might have resulted in maximum harvest of nitrogen (Marcellos, 1984). Whereas phosphorous and potassium was also removed significantly higher by soybean-gram cropping sequence.

Actual change of nutrients or fixed balance in soil was observed maximum in soybean-gram cropping sequence with respect to Nitrogen, Phophorous and Potassium respectively.

Actual change of nutrients or fixed balance in soil was observed maximum in soybean-gram cropping sequence with respect to Nitrogen, Phophorous and Potassium respectively.

Table 29: Balance sheet of nutrients after harvest of wheat and gram

The data related to balance sheet of nutrients after harvest of soybean has been depicted in table 29.

Cropping sequence	Initial available nutrients+addition through fertilizers (A)	Nutrients removed by crops (kg ha^{-1}) (B)	Nutrients in balance (expected value) (kg ha^{-1}) (A-B)=X	Final available nutrients (kg ha^{-1}) (C)	Actual change of nutrients fixed balance in soil(-) or gain(+) (kg ha^{-1}) (C-X)	Average (kg ha^{-1}yr^{-1})
Nitrogen						
Soybean-Wheat	341.37	58.22	283.15	341.25	+58.1	+58.1
Soybean-gram	355.71	59.03	296.68	355.36	+58.68	+58.68
Phosphorous						
Soybean-Wheat	31.29	14.48	16.81	36.20	+19.39	+19.39
Soybean-gram	30.38	9.24	21.14	34.84	+13.7	+13.7
Potassium						
Soybean-Wheat	415.93	63.70	352.23	419.31	+67.08	+67.08
Soybean-gram	419.60	27.98	391.62	423.66	+32.04	+32.04

From the above data results revealed that maximum amount of nitrogen was removed significantly by soybean-gram cropping sequence whereas phosphorous and potassium was removed significantly higher by soybean-wheat cropping sequence the high amount was removal may be due to intensive root system as well as their capacity to change in available form.

Actual change of nutrients or fixed balance in soil was observed maximum in soybean-gram cropping sequence with respect to Nitrogen, whereas fixed balance of phosphorous and potassium was observed more in soybean-wheat cropping sequence.

Chapter V

SUMMARY AND CONCLUSION

The field investigation relating to "Effect of integrated input management on nutrient balance under soybean based cropping system" was undertaken during kharif and rabi season of 2009-10 at EAD farm, College of Agriculture, Nagpur.

The experiment was laid out in strip plot design with three modules replicating four times. Treatment consisting of 5 t FYM (organic module), 100% RDF (inorganic module), 50% RDF + 5t FYM (integrated module). The soil of experimental site was clayey, alkaline in reaction with pH of 7.68, moderately high in organic carbon (7.00), medium in available nitrogen (296.91 kg ha^{-1}), moderately high in available phosphorous (26.58 kg ha^{-1}) and very high in available potassium (390.82 kg ha^{-1}), low in available sulphur (8.20 kg ha^{-1}), medium in exchangeable calcium and magnesium (53.45 and 15.46 (c mol (p^+) kg^{-1}), the micronutrient status of experimental site was recorded DTPA-extractable Fe (3.90 mg kg^{-1}), Mn (2.53 mg kg^{-1}), Zn (0.58 mg kg^{-1}) and Cu (1.30 mg kg^{-1}).

The observations recorded during this study are summarized and concluded as under :

The highest grain yield (15.41 q ha^{-1}) and straw yield (21.72 q ha^{-1}) of soybean was recorded under integrated module (50% RDF - FYM 5t ha^{-1}). The highest wheat equivalent grain yield (25.75 q ha^{-1}) was associated with the application of 100% RDF (inorganic module) followed by application of 50% RDF - 5t FYM + biofertilizer (25.44 q ha^{-1}).

Concentration of N, P and K in grain and straw of soybean was found non-significant as influenced by cropping system, while N concentration was found significant under various input management modules. P concentration in grain of soybean was also found significant under various input management modules, where K conc. was found non-significant. Maximum conc. of N in grain (6.84%) and P in grain (0.57%) was observed under integrated module (50% RDF +FYM @ 5t ha^{-1}) which was found at par with inorganic module (6.76%). The conc. of N in straw (1.17%), P (0.17%) and K (1.58%) recorded higher in inorganic module.

The conc. of N, P and K in grain and straw of wheat and gram was found significant except concentration of P in grain as influenced by cropping system. Application of 50% RDF + FYM @ 5t ha^{-1} to succeeding wheat crop recorded maximum concentration of K. The highest concentration of N in grain (2.53%) and straw (0.70%) was observed under inorganic module (100% RDF).

The total uptake of N (124.70 kg ha^{-1}), P (11.78 kg ha^{-1}) and K (40.62 kg ha^{-1}) was observed under soybean-gram cropping sequence (after harvest of soybean). The highest total uptake of N (130.84 kg ha^{-1}), P (12.41 kg ha^{-1}) and K (40.88 kg ha^{-1}) was observed under integrated module followed by inorganic module (100% RDF).

Data revealed over completion of 5th cycle of cropping system, the highest total uptake of P (14.48 kg ha^{-1}) and K (63.70 kg ha^{-1}) was observed in soybean-wheat cropping system while N found highest (59.03 kg ha^{-1}) in soybean-gram cropping system. The highest total uptake of N (69.37 kg ha^{-1}) was observed in integrated module (50% RDF + FYM 5t ha^{-1}), whereas uptake of P (12.34 kg ha^{-1}) and K (48.20m kg ha^{-1}) was observed in inorganic module (100% RDF).

Conc. of S and micronutrients (Fe, Mn, Zn and Cu) in grain and straw of soybean crop was found significant as influenced by cropping system. Maximum conc. of S and micronutrients in grain and straw of soybean crop was found higher in soybean gram cropping system. Maximum conc. of S in grain (0.26%) and Fe (27.2%), Mn (59.0%), Zn (50.0%), Cu (4.1%) was observed under integrated module (50% RDF + FYM 5t ha^{-1}) followed by inorganic module (100% RDF) while that of maximum conc. of S in straw (0.17%), Fe (26.6%), Mn (50.0%), Zn (33.0%), Cu(3.4%) observed under integrated module (50% RDF + FYM 5t ha^{-1}) followed by inorganic module (after harvest of soybean crop).

Conc. of S and micronutrients Fe, Mn, Zn & Cu in grain and straw of wheat and gram was found significant as influenced by cropping system. Maximum conc. of S and micronutrients (Fe, Mn, Zn and Cu) was observed under soybean-gram cropping system. After completion of 5^{th} cycle of cropping system maximum conc. of sulphur and micronutrients (Fe, Mn, Zn and Cu) in grain of wheat and gram was (0.17%) S, Fe (28.4%), Mn (55.0%), Zn (45.0%) and Cu (51.0%) and conc. of sulphur and micronutrients (Fe, Mn, Zn and Cu) in straw of wheat and gram (0.14%) S, Fe (26.8%), Mn (43.0%), Zn (38.0%) and Cu (3.0%) was observed under integrated module (50% RDF+FYM @ 5 t ha^{-1}) followed by inorganic module.

The total uptake of S (7.17 kg ha^{-1}) Fe (768.0 kg ha^{-1}) Cu (112.8% kg ha^{-1}), Mn (1794.0 kg ha^{-1}), Zn (1264.0 kg ha^{-1}) was observed under soybean-gram cropping sequence (after harvest of soybean). The highest total uptake of S (7.75 kg ha^{-1}), Fe (968.9 kg ha^{-1}), Cu ((137.5 kg ha^{-1}), Mn (2003.0 kg ha^{-1}), Zn (1513.0 g ha^{-1}) was observed under integrated module followed by inorganic module (100% RDF).

Data revealed over completion of 5^{th} cycle cropping system, the highest total uptake of S (8.81 kg ha^{-1}), Fe (1149.4 kg ha^{-1}), Cu (184.6 kg ha^{-1}), Mn (2131.0 kg ha^{-1}), Zn (1882.0 kg ha^{-1}), was observed in soybean-wheat cropping system. The highest total uptake of S (7.11kg ha^{-1}), Fe ((1243.0 kg ha^{-1}), Cu (182.4 kg ha^{-1}), Mn (2256.0 g ha^{-1}), Zn (1873.0 g ha^{-1}) was observed under integrated module (50% RDF + FYM 5 t ha^{-1}) followed by inorganic module (100% RDF).

The available N, P and K status of soil after harvest of soybean was significantly affected due to various cropping systems. Highest available N

(341.88 kg ha^{-1}) and K (430.83 kg ha^{-1}) was observed in soybean-gram cropping system, whereas available P (30.10 kg ha^{-1}) was found higher under soybean- wheat cropping sequences. The higher mean available N (353.72 kg ha^{-1}), P (31.57 kg ha^{-1}) and K (453.18 kg ha^{-1}) were recorded with the application of integrated modules (50% RDF + RYM @ 5t ha^{-1}).

The status available N and K in soil were found significantly higher when gram succeeded after soybean followed by soybean-wheat, However, the status of available P in soil differs significantly under soybean-wheat cropping system. The highest available N in soil (355.56 kg ha^{-1}) and available K in soil (423.66 kg ha^{-1}) was obtained under soybean-gram system and highest available p (36.20 kg ha^{-1}) was observed under soybean-wheat cropping system. The highest N (360.11 kg ha^{-1}), P (38.05 kg ha^{-1}) and K (425.36 kg ha^{-1}) was observed with integrated module (50% RDF + RYM 5t ha^{-1}).

The available S and exchangeable Ca^{++} and Mg^{++} status of soil after harvest of soybean was found significant under soybean-gram cropping system whereas exchangeable Ca^{++} was found statistically non-significant under cropping system. The highest available S (17.21 kg ha^{-1}), exchangeable Mg^{++} (27.13 c mol (p^{+}) kg^{-1}) and Ca^{++} (51.57 c mol (p^{+}) kg^{-1}) was recorded higher under soybean-gram cropping system. The higher mean value of available S (18.18 kg ha^{-1}), exchangeable Ca^{++} (54.65 c mol (p^{+}) kg^{-1}), Mg^{++} (27.65 c mol (p^{+}) kg^{-1}) was observed with integrated module (50% RDF + FYM @ 5t ha^{-1}).

The status of available sulphur and exchangeable Ca^{++} were found significantly higher when gram succeeded after soybean followed by soybean-wheat, however the status of exchangeable Mg^{++} in soil did not differ significantly by growing wheat and gram after soybean. The highest available S (17.50 kg ha^{-1}), exchangeable Ca^{++} (57.50 c mol (p^{+}) kg^{-1}), Mg^{++} (23.75 c mol (p^{+}) kg^{-1}) was observed with integrated module.

The DTPA-extractable micronutrient status of soil was found significant after harvest of soybean as influenced by cropping system except Fe and Mn that found non-significant with cropping system. Highest available Cu (4.77 mg kg^{-1}), Zn (5.20 mg kg^{-1}), Mn (8.98 mg kg^{-1}) was obtained under soybean-gram cropping system, whereas highest DTPA-extractable Fe (7.55 mg kg^{-1}) was obtained under soybean-wheat cropping system. The highest mean value of DTPA-extractable Cu (5.69 mg kg^{-1}), Fe (8.35 mg kg^{-1}), Zn (5.39 mg kg^{-1}) and Mn (9.92 mg kg^{-1}) was observed with integrated module (50% RDF + FYM @ 5 t ha^{-1}).

The DTPA-extractable Zn was found significant by growing wheat and gram after soybean. The DTPA-extractable Cu, Fe and Mn differs non-significantly by growing wheat and gram after soybean. The highest DTPA-extractable Cu (4.82 mg kg^{-1}), Fe (8.57 mg kg^{-1}), Zn (6.14 mg kg^{-1}), Mn (21.33 mg kg^{-1}) was obtained under soybean gram system. The highest DTPA-extractable Cu (4.86 mg kg^{-1}), Fe (9.06 mg kg^{-1}), Zn (6.22 mg kg^{-1}), Mn (22.73 mg kg^{-1}) was observed with integrated module (50% RDF + FYM 5 t ha^{-1}).

Soil pH, was found significant after harvest of soybean as influenced by cropping system, whereas electrical conductivity, and organic carbon content of soil was found non-significant with cropping system. Organic carbon content of soil after harvest of soybean was observed (7.69 g kg^{-1}) with the application of 50% RDF + RYM 5t ha^{-1} (integrated module) which was found significantly higher than organic (7.44 g kg^{-1}) and inorganic (7.34 g kg^{-1}) module under two cropping system.

At the completion of 5th cycle of cropping system, the mean value of organic carbon in soil was found significantly superior (7.85 g kg^{-1}) with the application of integrated module (50% RDF + FYM 5 t ha^{-1}) over rest of input management modules.

Conclusion

- Continuous use of inorganic fertilizers alone or in combination of 50% RDF along with organic and biofertilizers influence grain yield, uptake of nutrients organic carbon and available nutrients, over organic fertilizers alone.
- Thus inclusion of pulses in cropping system can check the resource degradation and sustain the productivity of cropping systems by improving the soil quality through maintenance of physio-chemical properties of the soil.
- Integrated use of organic manures and inorganic fertilizer is the only viable option for sustainable agriculture.
- Total uptake of major nutrients shows significant difference within input management modules and cropping system.
- Total uptake of micronutrients also shows significant difference within input management modules and cropping system.
- Application of 50% RDF in conjunction with organic manure shows significant change in soil properties under cropping system and input management modules.

Chapter VI

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Sr. No.	Name of Degree awarded	Year in which obtained	Division / Class	Name of awarding University	Subjects
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Place : Nagpur

Date : 31/05/2010

Signature of Student

APPENDIX

Statement was showing the weekly Meteorological Data at College of Agriculture, Nagpur for the period of July 2009 to March 2010.

Date	Met. Week	Temperature °C		Humidity		Total rainfall (mm)	No. of rainy days	Bright Sunshine hrs.	Wind speed $Kmhr^{-1}$	Evapo-ration (mm)	Remarks
		Max.	Min.	Mor.	Eve.						
25 to 01 July	26	36.1	24.4	82	62	139.4	5	--	6.6	5.1	
02 to 08	27	31.2	24.6	87	75	148.6	7	--	3.5	4.3	
09 to 15	28	30.5	24.4	88	73	166.7	5	--	6.3	2.8	
16 to 22	29	29.4	24	86	74	88.6	6	--	7.0	3.1	
23 to 29	30	30.0	24.0	81	67	46.1	3	--	6.2	3.4	
30 to 05 Aug.	31	32.2	25.8	71	79	--	--	--	6.1	4.0	
06 to 12	32	31.6	25.6	77	68	18.0	1	--	4.6	3.0	
13 to 19	33	31.4	25.2	78	70	--	--	--	4.2	3.0	
20 to 26	34	30.5	23.4	89	82	78.5	7	--	3.5	3.0	
27 to 02 Sept.	35	29.8	23.9	88	75	131.1	5	--	3.8	3.0	
03 to 09	36	31.9	23.9	86	70	45.6	3	--	5.3	3.9	
10 to 16	37	33.0	23.4	77	54	13.6	1	--	4.3	4.4	
17 to 23	38	35.2	24.2	70	46	--	--	--	3.2	4.9	
24 to 30	39	34.9	25.0	70	50	--	--	--	5.9	5.3	
01 to 07 Oct.	40	32.1	24.6	83	66	66.2	4	--	5.2	3.6	
08 to 14	41	33.3	20.6	67	41	--	--	10.2	2.8	4.1	
15 to 21	42	33.9	19.8	61	37	--	--	9.7	1.9	3.6	
22 to 28	43	32.8	15.5	57	26	--	--	9.9	2.2	3.8	
29 to 04 Nov.	44	32.9	14.8	54	26	--	--	9.3	2.4	3.9	
05 to 11	45	30.3	19.9	73	57	5.2	1	5.9	4.0	3.1	
12 to 18	46	30.6	21.3	86	65	29.2	3	3.5	4.1	2.0	
19 to 25	47	28.2	12.5	64	38	--	--	8.7	2.5	2.8	
26 to 02 Dec.	48	28.8	12.2	67	32	--	--	8.9	1.9	2.5	
03 to 09	49	29.8	13.5	75	40	--	--	7.5	1.5	2.3	
10 to 16	50	30.3	15.3	75	34	--	--	7.7	1.6	2.4	
17 to 23	51	28.4	14.8	73	43	3.2	1	7.6	3.3	2.7	
24 to 31	52	27.3	12.3	73	41	--	--	6.3	2.1	2.1	
1 to 7 Jan 10	1	27	10.1	56	30	--	--	8.8	3.0	2.2	
8 to 14	2	27	13.2	70	49	13.4	1	6.1	2.1	2.0	
15 to 21	3	27.2	9.2	58	32	--	--	8.7	2.3	2.6	
22 to 28	4	28.9	9.2	52	22	--	--	9.2	1.9	3.4	
29 to 4 Feb	5	29.8	13.1	60	34	--	--	8.3	2.5	3.4	
5 to 11	6	29.8	14.0	69	32	--	--	5.4	2.5	2.6	
12 to 18	7	31.6	17.9	68	34	7.4	1	6.5	3.1	3.9	
19 to 25	8	32.0	16.0	43	25	--	--	8.3	3.2	4.5	