Effect of Integrated Nutrient Management on Productivity of Maize (*Zea mays* L.) in South-East Rajasthan

दक्षिण–पूर्व राजस्थान में मक्का (*जिया मेज* एल.) की उत्पादकता पर समन्वित पोषक तत्व प्रबन्धन का प्रभाव

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This is to certify that this thesis entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agronomy,** embodies bonafied research work carried out by **Mr. Jitendra Kumar Balyan** under my guidance and supervision and no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The advisory committee also approved the draft of the thesis on 21/04/2004.

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Place: **Udaipur**
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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON PRODUCTIVITY OF MAIZE (*Zea mays* L.) IN SOUTH-EAST RAJASTHAN

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ABSTRACT

A field experiment entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** was conducted at Instructional Farm, Krishi Vigyan Kendra, Bhilwara during *kharif* season in two consecutive years 2001 and 2002. The objectives of the experiment were to study the effect of organic manure (FYM), chemical fertilizer and biofertilizer on maize. The soil of the experimental field was sandy clay loam in texture with medium fertility status (253.8, 26.17 kg N; 21.2, 22.2 kg P and 343.4, 346.6 kg K ha^{-1}) and alkaline in reaction with pH 8.14 and 8.10, respectively during 2001 and 2002. The experiment consisted with 30 treatment combinations comprising of 10 main plots [3 levels of FYM (0, 5 and 10 t ha^{-1}), 3 fertilizer level (50, 75 and 100% RDF) with one main plot control] and 3 sub plots with biofertilizer (control, *Azotobacter* and *Azotobacter* + PSB). These treatments were evaluated under split plot design with three replications.

The results reaffirmed pivotal role of integrated nutrient management in improving productivity of maize crop. Single source of nutrient did not fulfill the nutrient need of maize crop. Therefore, fertilization through organic manure, chemical fertilizers and biofertilizers were determining factor in achieving higher productivity of maize. Results of experiment reveal that application of 10 t FYM ha^{-1} significantly improved growth parameters like final plant height, LAI, LAD and dry matter accumulation at successive crop growth stages i.e. 30, 50, 70 DAS and at harvest, CGR (30-70 DAS) and NAR (50-70 DAS). Yield attributes *viz*., cobs $plant^{-1}$, grains cob^{-1}, grain weight cob^{-1} and one thousand grain weight also showed similar trend. Consequently with aforesaid dose of FYM enhanced grain, stover, biological yields and harvest index, which were increased by 43.89, 20.10, 20.64 and 11.38 per cent over no FYM. The N, P content and N, P and K uptake improved significantly through application

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of 10 t FYM ha^{-1}. Soil available N, P and organic carbon content also improved significantly with aforesaid dose of FYM after harvest of maize crop.

The results of the study have clearly show that application of chemical fertilizers from 50 to 100% RDF significantly improved final plant height, LAI, LAD, CGR and dry matter production at all successive crop growth stages. While, NAR increased at 50-70 DAS. This reflect into improved yield component *viz*., cobs plant^{-1}, grains cob^{-1} and grain weight cob^{-1}. The productivity of maize in terms of grain, stover and biological yields enhanced by 19.73, 12.46 and 14.23 per cent over 50% RDF. However, protein yield increased by 22.67 per cent with aforesaid dose. The uptake of N, P and K improved significantly at successive stages of crop growth with 100% RDF. Available soil P after maize crop harvest show marked improvement with 100% RDF.

Seed inoculation of *Azotobacter alone* and in combination with PSB proved significantly superior over control in respect of DMA plant^{-1}, LAI, LAD and CGR at all successive crop growth stages i.e. 50 DAS to harvest but NAR enhanced only at 50-70 DAS stage. Yield components *viz*., cobs plant^{-1}, grains cob^{-1} and grain weight cob^{-1} were also recorded maximum with aforesaid treatment. Maximum grain, stover and biological yields were 29.86, 72.45 and 103.20 q ha^{-1} , respectively with combined inoculation of *Azotobacter* + PSB. The nutrient N and P content concentration in plant at harvest and N, P and K uptake significantly higher at all successive crop growth stages with combined inoculation of *Azotobacter* + PSB. However, available P in soil at harvest was also maximum with combined inoculation.

Nutrient balance sheets indicate that balance of available N was observed negative with all treatments after maize crop harvest but with application of 10 t FYM ha^{-1} and 100% RDF obtained positive value 2.78 and 0.36 kg ha^{-1}. Further, balance of soil available P and K recorded positive with FYM, NPK fertilizer and biofertilizer but under control balance of P and K was found negative.

The economic evaluation indicated that application 10 t FYM ha^{-1} + 100% RDF along with seed inoculation of *Azotobacter* + PSB obtained net monetary returns of Rs. 19640 ha^{-1} with B:C ratio of 1.92 over control. However, aforesaid treatment obtained additional profit Rs. 11115 ha^{-1} as compared to control. While, 10 t FYM ha^{-1} + 75% RDF along with seed inoculation of *Azotobacter* + PSB indicated more remunerative in term of B: C ratio (1.96).

1. INTRODUCTION

Maize (*Zea mays* L.) rank third in total world production after wheat and rice and it is principal staple food in many countries, particularly in the tropics and sub tropics (FAO, 1999). It is also an important k*harif* food grain crop of India and it plays an important role in Indian agriculture economy both in terms of food for human being and feed for animals. However, it is consumed all over country including hilly and sub mountain tracts of northern India (Jain and Sharma, 1993). Being a C_4 plant, maize is capable to utilizing solar radiation more efficiently due to light saturation with higher radiation intensity. The theoretical potential productivity of hybrid maize was found 385 q ha^{-1} at the dry matter accumulation rate of 77 g/m^2/day (Loomis and Williams, 1963). Despite of high genetic potential and photosynthesis explorative crop, its average productivity in India is only 17.55 q ha^{-1} (Fertilizer Statistics, 1999-2000) which is deplorably low as compared to world average 42 q ha^{-1} (Rai, 2000). Average productivity of maize in India is also very low as compared to 54.48, 71.82, 82.98, 85.21 and 93.22 q ha^{-1} achieved in Australia, Canada, USA, France and Italy, respectively (FAO, 1999). Though maize is most adopted crop of Rajasthan and it is extensively cultivated in South and South-east parts of the Rajasthan, mainly Bhilwara, Udaipur, Rajsamand, Chittorgarh, Banswara and Dungarpur districts. The average productivity of Rajasthan and Bhilwara district is in order of 10.47 and 8.43 q ha^{-1} (Vital Agriculture Statistics, 2001-2002). Thus, the productivity of maize is very low in Bhilwara district as well as state level as compared to national average 17.55 q ha^{-1}. There is a wide gap between potential productivity and actual yield at the farmer's fields may be bridged by adequate and balanced use of nutrient with bio fertilizer.

In Indian agriculture plant nutrients are operating as a net negative balance 8 -10 million tonne per annum. India would have to produce around 300 million tonnes food grains by 2025 A.D to nourish over 1.4 billion population against the current estimated production about 203 million tonnes. For producing this much food grain India will need at least 45 million tonne of plant nutrients. Demand of chemical fertilizers would be 35 million tones consisting 5.6 to 8.8 million tonne P_20_5, 2.3 to 4.7 million tonne K_20 and the rest nitrogenous fertilizers. At least 10 million tonnes nutrients should come from organic manures, crop residues and biofertilizers. Thus, food security is very much linked with fertilizer input (Somani, 2001).

In modern agriculture use of chemical fertilizer alone is single most important input to increase the crop productivity. Kanwar and Sekhon (1998) estimated that all over the world fifty to sixty per cent increase in productivity of food grains is attributed with fertilizer use. Further, they also reported that due to continue use of fertilizers crop yield started declining and more input are needed to obtain the same yield. Nambiar and Abrol (1989) concluded a clear declined trend in the productivity even with application of N, P and K fertilizers. Hegde and Dwivedi (1992) also reported declining trend in the productivity even with balanced use of N, P and K fertilizers that was associated with soil physical conditions and imbalance in secondary and micronutrients under modern intensive farming.

It is well known that plant nutrients like nitrogen, phosphorus and potassium play a key role in proteins metabolism and these are most essential for all living creatures for their growth and development. Manures and fertilizers both play important role in maize cultivation. A liberal quantity of bulky manures should be applied in the field to get the yield potential. Hybrid and composite maize varieties exhibit their full yield potential only when supplied with adequate quantities of nutrients at proper time.

The balanced use of NPK fertilizers and use of biofertilizers are some useful practices that improve physical condition of soil and enhance nitrogen use efficiency of applied fertilizer in maize. Calculation show that one per cent increase in recovery rate of N fertilizer would result in a saving of 98,000 tonnes of N, which is in term of additional crop response, would be equivalent to one million tonne of food grain. No single source of plant nutrients may be it chemical fertilizers, organic manures, crop residues or biofertilizers can meet the entire nutrient need of crops in modern agriculture. Rather, they need to be used in an integrated manner by following a management technology, which would be appropriate, economically viable, socially acceptable and ecologically sound.

The role of soil organic carbon in maintaining soil fertility and productivity is well recognized from the time immemorial and its maintenance in the soil is of almost concern under modern intensive farming. Amongst the organic manure, FYM is a well known source which release nutrients into readily available form after microbial decomposition. The results of long-term addition of organic materials into the soil have resulted in increase soil biological activity (Collins *et al*., 1992 and Fauci and Dick, 1994). Organic matter addition in soil not only acts as a storehouse of macro and micronutrients but also is known to influence physical, chemical and biological properties of soil. The increase in microbial activity results into enhances activity of enzymes that play a key role in the transformation, recycling and availability of plant nutrients. However, total nutrients requirement of crop can not meet out by organic manures, since the nutrients requirement is very high in contrast to their availability. Continuous dressing with farm yard manure (FYM) was found to be effective in stabilizing productivity under low to medium cropping intensity, while integrated use of organic and chemical fertilizer provided stability in crop production under the modern intensive farming (Nambiar *et al*., 1989). Combination of organic manure with inorganic fertilizer may be beneficial to maximize the crop productivity and improve soil properties (Gaur and Kumawat, 2000).

In order to keep pace with the growing population pressure and diminishing land energy resources, agriculture has need to be more intensive knowledge. In recent years, contineous hike in price and scarcity of chemical fertilizer, it has real need to search out some alternative sources for crop nutrition to increase the production and sustain the productivity. In this approach microbial fertilization with *Azotobacter* and phosphorus solubilizing bacteria (PSB) have been found promising to improve nitrogen status and phosphorus availability in soil and increased crop yield, respectively. *Azotobacter* is able to fix atmosphere nitrogen through non-symbiotic process. *Azotobacter* a free living heterotopic nitrogen fixing bacteria encountered in natural to alkaline soil conditions not only provides the nitrogen but produce a variety of growth promoting substances. Some of these growth promoting substances are indole acetic acid, gibberellin, vitamins B and anti fungal substances (Somani, 1987). Another important characteristic of *Azotobacter* associated with crop improvement are excretion of ammonia in the rhiosphere in presence of root exudates, which helps in modification of nutrient uptake by the plant. These strains are better competitors than non-excreting strains. Shende and Apte (1982) reported that seed inoculation with *Azotobacter chroococecum* to maize crop increase grain yield at IARI, New Delhi and Dharwar district, Karnatka. *Azotobacter* brings out an improvement role in nitrogen economy and increase grain yield (Karisangan *et al.*, 1978). *Azotobacter* release growth promoting substance like gibberellins, indole-3-acetic acid (IAA) etc. which might be responsible for better growth of plants (Brown and Burligham, 1968 ; Shende *et al*., 1977 and Wani, 1990).

High yielding crops may remove as much as 10 per cent of total phosphorus from upper 15 cm of fertile soils and remain quantity of this nutrient has lock up in soils which is present in non available form. Microorganisms play important role in the mobilization and immobilization of phosphorus, solubilization of insoluble inorganic compounds is brought about by phosphorus solubilizing bacteria (PSB) by the production of organic acids. Phosphate solubilizing microorganism particularly the soil bacteria belonging to the genera *Pseudomonas* and *Bacillus* and fungi belonging to the genera *Penicillium* and *Aspergillus* posses the ability to transfer insoluble phosphate into soluble forms. The work on phosphate solubilizing bacteria began in India with phosphobacterin culture obtained from the USSR.

The PSB secrets organic acids and these acids lower the soil pH and bring about the dissolutions of bound forms of phosphates (Subba Rao, 1984).

Available phosphorus in most of Indian soils is insufficient and the applied phosphorus fertilizers become unavailable within a short period due to its chemical fixation in soils. The transformation of applied phosphorus to unavailable form and import of phosphatic fertilizers are the major problems in phosphate fertilization. Hence there is a need to improve phosphorus nutrition of crop with the help of certain beneficial soil microorganisms. Phosphate solubilzing bacteria (PSB) not only solubilize organic and inorganic phosphorous in soil but also make available added phosphorous and thereby increasing P availability and crop yields (Gaur and Gaind, 1992). Several research workers concluded that different cereals plant growth and grain yield increased with PSB inoculation (Gaur, 1985; Meena, *et al.,* 1991 and Sushila and Giri, 2000).

In India, intensive agriculture involving exhaustive HYV of cereals has led to heavy withdrawal of nutrients from the soil during past three decades. Since the nutrient turnover in soil plant system is considerably high under intensive farming, neither the chemical fertilizer nor the organic or biological sources alone can achieve production sustainability. Integrated nutrient management with a combination of different sources of nutrients is necessary for successful crop production. It aims at achieving a harmony with the use of fertilizers for sustained crop productivity without any deterious effects on the soil health and environment.

In view of these facts, there is a necessity to plan a field experiment for economic use of applied nutrients for maintenance of soil fertility at sustainable level of production with organic manure and chemical fertilizer in conjunction with biofertilizers on maize productivity. Thus, field experiment entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** was conducted with the following objectives:

(i) To study the effect of organic manure, chemical and biofertilizers on productivity of maize.

(ii) Interaction studies on organic manure, chemical and biofertilizers on productivity of maize, if any.

(iii) To work out economically viable treatment combination for maize production.

2. REVIEW OF LITERATURE

A brief review related to the research work on the effect of integrated nutrient management on maize productivity is presented in this chapter. The basic concept under lying integrated plant nutrient system is the maintenance or adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefits from all possible sources of plant nutrient in an integrated manner. The appropriate combination of chemical fertilizers, organic manures and biofertilizers varies according to the system of land use, ecological conditions and socio-economic status of farmers. Continuous increasing the cost of chemical fertilizers, sustain soil fertility and sustainable crop production issue have greater importance in modern Indian agriculture. Single source of plant nutrients (organic, chemical or biological) not able to satisfy the need of all the essential elements, which needs by crop for its growth and development. The review cited on effect of FYM, NPK fertilizer at different levels and use of biofertilizers on maize and allied crops have been reported to increase growth parameters, yield attributes, yield and nutrient content by several workers.

2.1 EFFECT OF FYM/ORGANIC MANURES

The FYM is one of the most important agricultural byproduct. FYM not only supply plant nutrients to soil but also improves physical condition of soil and increase productivity. It also play a vital role for maintaining sustainable soil productivity. Inclusion of FYM regulates nutrient supply, uptake and improve crop yield. FYM is considered most important organic farm input due to its easy availability to farmers, low-cost, effectiveness in maintaining soil physical health and slow capacity to release plant nutrients.

2.1.1 Growth parameters

Guar and Rao (1984) reported that application of FYM @ 10 t ha^{-1} increase the leaf area index of maize. Khanday and Thakur (1990) at Palampur, Himachal Pradesh, observed that varying level of FYM (0, 10 and 20 t ha^{-1}) significantly increased the plant height, leaf area index and dry matter accumulation of maize under rainfed conditions. Gangwar and Singh (1992) recorded significant increase in dry matter accumulation by 29.9 and 34.7 per cent as compared to control(137 g $plant^{-1}$) during 1988 and 1989, respectively in sorghum .

De Toledo *et al.* (1993) observed that application of compost in maize crop increased the leaf area index and dry matter accumulation. Sekhon and Agarwal (1994) observed that application of organic fertilization either through green manuring of cowpea or FYM increased leaf area and leaf longevity but hastened leaf appearance as compared to no organic fertilization.

A field experiment conducted at Rajendra Nagar, A.P., indicated that significant increase in plant height and dry matter production in *rabi* maize with the application of poultry manure (Madhavi, *et al.*, 1995).

Rameshwar and Singh (1998) at Palampur (H.P.) recorded significant increase in plant height, dry matter production and interception of light in maize crop under FYM fertilization @ 10 t ha^{-1} as compared to no FYM. Similarly, significant increase was recorded in plant height and leaf area index with application of FYM as compared to no FYM under rainfed condition in winter maize (Vadivel *et al.*, 2001).

Pathak *et al.* (2002) reported that application of 75 per cent recommended dose of NPK through fertilizer and 25 per cent N through FYM significantly increased plant height, leaf area index, dry matter accumulation, net assimilation rate and crop growth rate of maize crop on loam soils of BAU, Ranchi (Bihar). Likewise, Verma *et al.* (2002) observed that application of 50 per cent N through fertilizer and 50 per cent N through FYM recorded more number of plant, plant height and number of leaves in maize crop.

2.1.2 Yield and yield attributes

Singh *et al.* (1983) reported that significant increase in grain yield of maize was observed with application of 12 t FYM ha^{-1} as compared to control during the investigation at Ludhiana (Punjab). Similarly, significant increase by 50 per cent in grain yield of rainfed maize was recorded with application of 10 t FYM ha^{-1} over control (Grewal *et al.*, 1982).

In a field experiment on Sandy loam soils at Ludhiana (Punjab) revealed that application of 8.5 and 17.0 t FYM ha^{-1} increased maize grain yield by 4.3 and 7.4 q ha^{-1}, respectively (Singh and Brar, 1985). But in another continuous four years experiment Sharma (1987) concluded that application of 5 t FYM ha^{-1} could not produced significant improvement in grain yield of maize.

Negi *et al.* (1988) suggested that application of 10 t FYM ha^{-1} significantly increased grain weight cob^{-1}, 1000-grain weight, grain and stover yield of maize over no FYM. Gaur (1991) concluded that application of FYM at 30 days before sowing in maize crop produced highest grain yield (26.5 q ha^{-1}) as compared to FYM application at 45 and 15 days before sowing produced grain yield by 24.0 and 24.9 q ha^{-1}, respectively.

Sriniwasan (1992) suggested that application of 10 t FYM ha^{-1} significantly increased grain and stover yield by 32.3 and 24.3 per cent over no FYM (36.55 and 57.84 q ha^{-1}), respectively. Where as, Khandey *et al*. (1993) reported that application of FYM @ 20 t ha^{-1} significantly increased number of grains cob^{-1} in maize.

Significant increase in grain yield and yield attributes of pearl millet was observed with application of organic fertilization (Lal *et al*., 1995). Similarly, Patel *et al*. (1995) reported that significant increase in yield and yield attributes of pearl millet with application of organic matter over no FYM . Whereas, Deshmukh *et al*. (1996) also reported that yield attributes of sorghum were significantly increased with application of organic matter.

Khandey and Thakur (1991) observed that varying levels of FYM failed to produce significant increase in harvest index of maize. While, application of 10 t FYM ha^{-1} alone significantly increased grain yield of maize over no FYM (Patiram, 1996). Similarly, Mahajan (1996) conducted a field experiment at Bajaura (Madhya Pradesh), revealed that application of FYM increased 27 per cent higher grain yield of maize over control. Similarly, Singh *et al*. (1996) reported that application of 10 t FYM ha^{-1} produced 9.2 q ha^{-1} additional yield of maize as compared to no FYM (23.3 q ha^{-1}).

Suri and Puri (1997) suggested that application of 10 t FYM ha^{-1} produced highest grain yield (18.84 q ha^{-1}) as compared to no FYM. Rameshwar and Singh (1997) studied that application of 10 t FYM ha^{-1} gave significantly higher yield attributes of maize *viz*. cobs $plant^{-1}$, grains cob^{-1}, grain weight cob^{-1} and 1000-grain weight (1.02, 356, 89.4 and 250.1 g, respectively). Further they reported that a significant increase in grain and stover yields by 16.6 and 24.9 per cent over control (37.09 and 85.70 q ha^{-1}), respectively.

In a field experiment conducted at Udaipur, Rajasthan by Gaur (1998) reported that application of 10 t FYM ha^{-1} increased maize grain yield by 7.7 per cent as compared to control (13.67 q ha^{-1}).

Vadivel *et al*. (2001) reported that significant increase in cob length, cob girth, seed index, grain and stover yields were observed due to application of organic manure over control. Similarly, Kumar and Puri (2001) reported that application of 15 t FYM ha^{-1} significantly increased the cob length, grain cob^{-1}, seed index, grain and stover yields of maize.

Pathak *et al.* (2002) conducted an experiment at BAU, Ranchi (Bihar), on loam soils revealed that application of 75 per cent of recommended dose of NPK through fertilizers and 25 per cent substituted through FYM significantly increased number of cobs plant^{-1}, cob length, cob girth, 1000-grain weight and grain yield over no FYM in maize crop. Similarly, Patidar and Mali (2002) reported that application of 10 t FYM ha^{-1} in sorghum significantly increased grain and stover yield by 12.5 and 9.4 per cent, respectively over no FYM.

A field experiment conducted during 1996 and 1997 at Kota, Rajasthan, revealed that application of 60 per cent NPK through fertilizers and 40 per cent N through FYM increased the grain yield by 21.6 per cent over recommended dose of N and P in wheat crop (Deshveer *et al.*, 2002).

An experiment was conducted on sandy loam soils at Agra (Uttar Pradesh), with varying levels of FYM (0, 5 and 10 t ha^{-1}) revealed that application of 10 t FYM ha^{-1} increased grain and straw yields of wheat by 20.4 and 21.5 per cent over no FYM (30.7 and 50.7 q ha^{-1}) respectively (Singh and Singh, 2002).

2.1.3 Nutrient content and uptake

A field experiment conducted under mid hill conditions of Himachal Pradesh inferred that each successive increase in FYM application from 0 to 20 t ha^{-1} increased total uptake of N by maize during first year of experimentation but during second year only 20 t FYM ha^{-1} was found significantly superior over control. While, other levels were at par with each other (Khandey and Thakur, 1991).

Panwar *et al*. (1991) observed that application of biogas slurry with successive increase from 0 to 10 t ha^{-1} enhanced uptake of N, P and K by grain and stover of maize and total nutrient uptake was also significantly increased. However, differences between 5 and 7.5 t slurry ha^{-1} was not significant in case of N uptake by stover.

A field experiment planned at Palampur Himachal Pradesh by Sharma *et al.* (1995) observe that application of 20 t FYM ha^{-1} in maize increased phosphorus content and uptake by 44 and 182 per cent in grain of maize crop as compared to control (0.21% and 4.5 kg ha^{-1}, respectively).

Kumar (1998) reported that application of 10 t FYM ha^{-1} in sorghum increased N, P and K uptake 10.34, 13.97 and 14.73 per cent, respectively over no FYM (100.4, 19.32 and 196.7 kg ha^{-1}, respectively). Similarly, a field experiment was conducted by Patidar and Mali (2002) at Udaipur (Rajasthan), application of 10 t FYM ha^{-1} in sorghum increased N, P and K contents by 4.6, 4.6 and 3.15 per cent in grain and 4.02, 2.5 and 6.65 per cent in stover over no FYM (1.66, 0.396 and 0.538 per cent in grain and 0.572, 0.233 and 1.759 per cent in stover, respectively.

Ramamurthy and Shivshankar (1996) reported that application of 10 t FYM ha^{-1} increased uptake of N, P and K in maize crop by 22.5, 45.37 and 26.8 per cent as compared to control (210.6, 21.64 and 63.70 kg ha^{-1}, respectively).

Singh and Singh (2002) observed that in wheat successive increase in FYM levels from 0 to 10 t FYM ha^{-1} enhanced nitrogen, phosphorus and potassium uptake by 30.74, 30.58 and 35.58 per cent in grain as compared to no FYM (116.1, 11.1 and 28.2 kg ha^{-1}, respectively) and 39.67, 49.18 and 27.69 per cent more in straw as compared to no FYM (31.0, 6.1 and 97.5 kg ha^{-1}, respectively).

2.1.4 Soil nutrient status

Doney *et al*. (1988) observed that successive increase from 0 to 90 t FYM ha^{-1} $year^{-1}$ enhanced initial organic carbon (%) status of soil and they observed organic carbon (%) status in soil by 0.93 per cent with 90 t FYM ha^{-1} as compared to no FYM (0.45).Similarly, significant increase in organic carbon, porosity, hydraulic conductivity and decreasing bulk density and pH of the soil were observed with FYM application (Singh and Tomer, 1991).

Gupta and Mali (1993) reported that application of FYM Significantly influenced the soil properties by increasing organic carbon and decreasing pH of the soil. Singh *et al*. (1996) reported that application of biogas slurry @ 15 t ha^{-1} increased available N, P and K status with positive balance by 2.8 and 11.6 kg ha^{-1} as compared to untreated plots (negative balance of N and P 4.6 and 1.6 kg ha^{-1}, respectively) after end of the cropping system.

Mohanty and Rajarajan (2000) observed that application of FYM increased N, P and K status in treated plots at the end of maize crop over no FYM. While Singh and Singh (2002) reported that addition of 15 t FYM ha^{-1} improved the physico-chemical properties of the soil along with mineralization of N and P.

2.2 EFFECT OF NPK

2.2.1. Growth parameters

Angiras and Singh (1988) at Palampur, Himachal Pradesh, during the study of two consecutive years recorded significant increase in plant height at 120 DAS, number of functional leaves at 90 DAS and dry matter accumulation $plant^{-1}$ with 150 per cent recommended dose of fertilizers as compared to 100 per cent recommended dose of NPK (120:60:60 kg ha^{-1}).

Berzsenyi (1988) in Hungary, observed that application of N at varying level 0, 80, 160 and 240 kg ha^{-1} with recommended of dose of P and K at each level of N increased the leaf area index 2.58, 3.87, 4.26 and 4.39, respectively.

At Solan, Himachal Pradesh, two years pooled results indicated that each successive increment in fertility levels from 50 to 125 per cent recommended dose of NPK significantly increased functional leaves $plant^{-1}$ at 60 DAS, plant height and dry matter accumulation $plant^{-1}$ at harvest (Thakur and Singh 1990).

Gangwar and Singh (1992) observed that application of 100 per cent recommended dose of fertilizer in sorghum significantly increased the dry matter production by 70.6 per cent at harvest as compared to control (121.00 q ha^{-1}).

In a field experiment conducted at Agra, Uttar Pradesh (Singh and Kumar, 1995) observed significant increase in dry matter production at harvest by 46.34 and 13.20 per cent when maize crop was fertilized with 100 per cent recommended dose of NPK (100: 60 : 60 kg ha^{-1}) and 50 per cent recommended dose of fertilizer over no fertilizer (20.5 and 26.5 gm $plant^{-1}$, respectively).

Jat (1998) recorded 2.02 per cent increase in leaf area index with the application of 60 kg N and 30 kg P_2O_5 ha^{-1} as compared to control (3.45). Further, application of 60 kg N and 30 kg P_2O_5 ha^{-1} significantly increased the dry matter production by 2.22, 1.95 and 3.18 per cent at 30, 60 DAS and at harvest as compared to control (11.25, 64.56 and 164.81 g $plant^{-1}$, respectively).

Nehra *et al*. (2001) reported that application of recommended dose of NPK in wheat crop recorded highest value of dry matter accumulation and leaf area index as compared to no fertilizer. Similarly, Prasad *et al*. (2001) also studied that application of fertilizer by 50, 75 and 100 per cent of recommended dose increased significantly plant height of wheat and paddy crops.

2.2.2 Yield and yield attributes

Two years studies at Solan, Himachal Pradesh, revealed that each successive increase in fertility level 50 per cent RDF up to 100 per cent recommended dose of NPK (120:60:40 kg ha^{-1}) significantly increased cobs $plant^{-1}$, test weight and grain yield of maize (Thakur and Singh, 1990). Similarly, at solan (H.P.), application of 100 per cent RDF of NPK in maize significantly enhanced stover yield over 50 and 75 per cent RDF but at par with beyond 100 per cent recommended dose of fertilizer (Thakur *et al*., 1992).

Shah *et al.* (1992) explained that due to application of N and P (120:60 kg ha^{-1}) increased in maize grain (88.2 per cent), stover yield (62.7 per cent) and harvest index (10.2 per cent) over control with their respective values 22.5, 51.0 q ha^{-1} and 30.26 per cent. Similarly, Shrivastava and Singh (1992) reported that application of NPK (80:40:40 kg ha^{-1}) increased grain yield by 82.8 and 56.3 per cent, respectively over control (18.7 and 21.1 q ha^{-1}), respectively during both year of experimentation.

Paradkar and Sharma (1994) examined that application of NPK (150:75:60 kg ha^{-1}) in maize increased the number of cobs ha^{-1} by 9.4 per cent over 100 kg N ha^{-1} alone (95,000 cobs ha^{-1}). Studies carried out at Hoshiarpur and Kapurthala districts of Punjab, obtained a consistent increase in grain yield of maize with each increment of fertilization at both places. Further, maximum grain yield was recorded with 100 per cent recommended dose of NPK (120:60:30 kg ha^{-1}) and it was significantly superior over 75, 100 and 125 per cent recommended dose of NPK (Gill *et al*., 1994).

In a field experiment conducted at Palampur (H.P.) reveal that increasing rate of 100 to 200 per cent recommended dose of NPK recorded an increase in grain yield of maize with successive increases in fertilizer level (Rameshwar and Singh, 1998).

Jat (1998) obtained 4.72, 4.18 and 3.96 per cent increase in grain yield, stover yield and harvest index in maize when intercropped with soybean and fertilized with 60:30 kg N and P ha^{-1} over control (37.66, 84.58 q ha^{-1} and 30.46 per cent, respectively).

Ravankar and Deshmukh (2000) reported that application of 100 per cent RDF of NPK was proved significantly superior over 75 per cent RDF of NPK. Further, they reported that 150 per cent NPK enhanced significantly grain yield of maize over control.

Prasad *et al.* (2001) reported that application of fertilizer at 50, 75 and 100 per cent recommended dose of NPK ha^{-1} increased 112.5, 71.4 and 100 per cent grain yield in wheat, barely and paddy over control, respectively.

Nehra *et al.* (2001) reported that application of increasing levels of NPK increased grain and straw yields of wheat and get highest value under recommended dose of NPK. Mundra *et al*. (2002) conducted an experiment at Udaipur, Rajasthan, result reveal that significant increasing trend in grain, stover and biological yields of maize with increasing level of N and P (100 to 150 per cent of recommend dose).

2.2.3 Nutrient content and uptake

Application of 60 kg N + 30 kg P_2O_5 ha^{-1} increased N content by 2.50 and 3.63 per cent in cob and stover of maize over 60 kg N ha^{-1} alone (1.355 and 0.55 per cent), respectively (Menaria, 1987). Similarly, Karawasara (1993) reported that application of N and P (60-30 kg ha^{-1}) in maize increased total N and P uptake by 69 and 16.9 kg ha^{-1} over 30 kg N + 15 kg P_2O_5 ha^{-1} (49.8 and 14.4 kg ha^{-1}, respectively).

A field experiment conducted at Agra, Singh and Kumar (1995) observed that application of NPK (100:60:60 kg ha^{-1}) on maize recorded significant increase in total uptake of NPK by 84.1,85.1and 71.6 per cent more over control (499.6, 24.2 and 471.6 kg ha^{-1}, respectively).

Jat (1998) observed that significant increase in NPK contents in maize grain (1.37, 3.12 and 2.39 per cent) and in stover (2.48, 4.69 and 0.76 per cent) with application of 60 kg N and 30 kg P_2O_5 ha^{-1} over control (1.741, 0.352 and 0.418 per cent in grain and 0.603, 0.149 and 1.439 per cent stover, respectively). Further, he observed an increase in total NPK uptake by 4.14, 5.31 and 4.49 per cent with 60 kg N + 30 kg P_2O_5 ha^{-1} over control (119.57, 26.51 and 139.75 kg ha^{-1}), respectively.

Sharma and Gupta (1998) reported significant increase in total N and P uptake in maize with each successive increment in fertility level from 50 to 100 per cent NPK. Similarly, A field experiment conducted during two consecutive years at Udaipur, Goel and Somani (2002) observed that application of 100 per cent RDF significantly increased NPK uptake in maize grain by 51.04, 41.68 and 31.13 per cent over 50 per cent RDF (47.09, 9.40 and 93.40 kg ha^{-1}, respectively).

2.3 COMBINED EFFECT OF ORGANIC (FYM) AND INORGANIC (NPK) FERTILIZATION

2.3.1 Growth parameters

At IARI, New Delhi, Sharma (1983) reported that application of 12 t FYM ha^{-1} along with increasing level of NPK (60:30:30 to 120:60:60 kg ha^{-1}) in maize significantly improved plant height and number of leaves $plant^{-1}$ as compared to only fertilizer level. Further, results indicated that significant increase in plant height and number of leaves $plant^{-1}$ were observed with each successive increment in fertilizer level up to 120:60:60 kg ha^{-1} applied through chemical fertilizers.

A field experiment was carried out in *kharif*, 1994 at Palampur (Himachal Pradesh) by Suri *et al*. (1996) reported that significant increase in leaf area index, dry matter accumulation, root weight and root density of maize crop noted with application of 5 t FYM ha^{-1} with 100 per cent recommended dose of NPK over no FYM.

Chandrashekara *et al*. (2000) suggested that application of poultry manure 10 t ha^{-1} with recommended dose of NPK produced taller plant of maize as compared to NPK alone. On sandy loam soils at North campus of Bidhan Chandra Krishi Viswavidhyalaya, Coochbehar, West Bengal, during 1994-1997, application of 100% recommended dose of NPK along with 10 t FYM ha^{-1} significantly increased plant height, number of primary and secondary branches $plant^{-1}$ of mustard crop (Mandal and Sinha, 2002). Similarly, Kewalanand (2002) while conducting a field experiment in sandy loam soils at Pantnagar recorded significantly higher values of growth character *viz*. plant height, number of branches $plant^{-1}$ and total dry biomass yield due to application of 10 t FYM ha^{-1} with 75% recommended dose of NPK in wild mungbean (*Phaseolus trilobus*).

Paradkar (2003) observed significant increase in plant height of soybean with application of 10 t FYM ha^{-1} along with 100% recommended dose of NPK over recommended dose of NPK only.

2.3.2 Yield attributes and yield

Srivastava (1985) reported that application of 15 t FYM ha^{-1} increased grain yield by 12.94 per cent over 120 kg N ha^{-1} alone. Further, he reported that when crop fertilized with 120 kg N ha^{-1} + 60 kg P_2O_5 ha^{-1} along with 10 t FYM ha^{-1} produced 5.28 per cent higher grains cob^{-1} over no FYM.

Bhardwaj *et al.* (1994) reported that application of FYM with 100% NPK increased grain yield by 9.95 q ha^{-1} and 3.75 q ha^{-1} in rice and wheat crops, respectively over NPK alone. At Rajendranagar (Andra Pradesh), Madhavi *et al*. (1995) observed highest yield of r*abi* maize with 100 per cent recommended dose of NPK along with 4.5 t poultry manure ha^{-1}

Kamlakumari and Singaram (1996) reported that application of 10 t FYM ha^{-1} with NPK (135:67.5:35 kg ha^{-1}) enhanced grain yield of maize by 63 per cent over control. A field experiment conducted at Palampur, Himachal Pradesh revealed that application of 5 t FYM ha^{-1} along with recommended dose of NPK increased grain and stover yield of maize by 11.5 and 6.3 per cent, respectively. Further, they reported 5 t FYM ha^{-1} reduced the NPK requirement in maize by 60, 50 and 40 per cent for targeted yield 30, 40 and 50 q ha^{-1}, respectively (Suri *et al*., 1996).

Yeboua *et al*. (1996) reported that combination of organic manure along with chemical fertilizer increased the grain yield of maize by 170 to 300 per cent as compared chemical fertilizer only. In a long-term experiment conducted at Ludhiana enumerated that application of N alone or in combination with P did not produce as much maize grain as compared to combined application of NPK (Biswas and Benbi, 1997).

Jha *et al*. (1997) reported that application of 5 t FYM ha^{-1} along with NPK fertilizer significantly increased the grain and stover yield of maize as compared to their respective doses of NPK without FYM. Field experiment conducted at Akrot , Himachal Pradesh, under sub-tropical condition result reveal that application of 10 t FYM ha^{-1} along with 100 per cent recommended dose of NPK (90:45:30 kg ha^{-1}) produced significantly higher grain yield of maize (Suri *et al*., 1997).

A field experiment conducted on alluvial soils for three years at Ludhiana, Punjab reveal that application of FYM along with 100 per cent recommended dose of NPK in maize increased grain yield by 54 per cent over 100 per cent NPK alone (Tandon, 1997). An investigation conducted for three years on silt clay loam soils at Palampur, data revealed that application of 10 t FYM ha^{-1} along with 50 per cent recommended dose of NPK produced maximum grain yield of maize-wheat cropping system as compared to 100 per cent NPK alone (Kumar and Singh, 1997).

During three years of experimentation at Gayeshpur, West Bengal, application of FYM 10 t ha^{-1} along with 75 per cent recommended dose of NPK gave best results in both kh*arif* and *rabi* seasons in fodder based system of oat, maize, sorghum and grain rice crops (Nanda *et al*., 1998). A field experiment conducted at Dheradun, application of 5 t FYM ha^{-1} along with recommended dose of NPK gave maximum grain yield of maize and wheat as compared to 100% NPK alone (Sewa Ram, *et al*., 1998).

Application of FYM with 75 per cent recommended dose of NPK produced grain yield at par that obtained with 100 per cent recommended dose of fertilizer, thus indicated that organic fertilization can substitute chemical fertilization by 25 per cent (Sharma and Gupta 1998).

In a field study at Palampur, application of 10 t FYM ha-1 in maize crop along with 100, 125 and 150 per cent recommended dose of NPK gave significantly higher grain yield with increasing rates (Rameshwar and Singh, 1998). A field experiment was conducted at Jashipur (Orrisa) reveal that application of 100 per cent recommended dose of NPK (80:40:40 kg ha^{-1}) produced significantly more grain yield over 5 t FYM ha^{-1} and FYM + 50%

recommended dose of NPK (5.74 and 22.46 q ha^{-1} respectively) but all of these treatments were superior over control(4.42 q ha^{-1})Sahoo and Panda, 1999.

Chandrashekara *et al*. (2000) reported that application of poultry manure10 t ha^{-1} along with recommended dose of NPK in maize produce longer cob (14.35 cm) of more diameter (15.6 cm) and heavier cob weight (170.5 g cob^{-1}) as compared to NPK dose alone. Further, they reported that increase in cob length, cob girth and grain weight $plant^{-1}$ was by 13.1, 23.8 and 53.2 per cent, respectively as compared to NPK only. In continuation they further reported that application of poultry manure 10 t ha^{-1} with recommended dose of NPK (150:75:37.5 kg ha^{-1}) produce higher grain and fodder yield (50.8 and 74.4 q ha^{-1}, respectively) as compared to rest of the treatments.

The experiment conducted during two consecutive years at Sekhampur (W.B.), reveal that rice crop recorded highest value of all yield attributes and yield with 75% RDF (NPK) + 3 t FYM ha^{-1} over NPK dose alone (Bandayopadhyay and Puste, 2002).

Raj Singh (2002) observed that application of 2.5 t FYM ha^{-1} along with recommended dose of NPK in clusterbean significantly increased 1000-seed weight, pods $plant^{-1}$ and seeds pod^{-1} as compared to NPK alone. Further, he observed that in this treatment gave maximum seed and stover yields over 100% NPK alone.

2.3.3 Nutrient content and uptake

In long-term experiment, Lal and Mathur (1989) observed a significant improvement in nutrient uptake by maize with application of FYM along with 100 per cent RDF over control. At Solan, Himachal Pradesh application of increasing level from 0 to 10 t FYM ha^{-1} along with phosphorus (0, 30 and 60 kg P_2O_5 ha^{-1}) increased N and P uptake in maize and wheat (Negi *et al*., 1992).

At Agra (Uttar Pradesh), Singh and Kumar (1995) observed Significant increase in total N, P and K uptake by 84.1, 85.1 and 71.6 per cent in maize crop fertilized with NPK (100: 60: 20 kg ha^{-1}) over control (499.6, 24.2 and 471.6 kg ha^{-1}, respectively).

A long term experiment was conducted on clay loam soils at Coimbatore, Tamil Nadu, indicate that application of 10 t FYM ha^{-1} along with 100 per cent recommended dose of NPK (135:67.5:35 kg ha^{-1}) significantly improved N, P and K uptake by grain and stover (Kamlakumari and Singaram, 1996). At Rajori, Sharma and Gupta (1998) observed significant increase in total uptake of N and P nearly by 6.61 and 5.84 kg ha^{-1} higher in maize with FYM along with NPK over uptake of these under NPK only. Santhy *et al.* (2001)

reported that application of 100 per cent NPK along with 10 t FYM ha^{-1} significantly increased N, P and K uptake by finger millet, cowpea and maize.

2.3.4 Soil Nutrient status

Nambiar (1989) reported that application of organic manure along with fertilizers sustained the productivity of soil and thereby sustaining the higher crop yield. Similarly Nand Ram (1995) reported that availability of nitrogen, phosphorus and potash was enhanced by combined application of NPK and FYM.

On clay loam soil at Coimbatore, application of 10 t FYM ha^{-1} along with NPK fertilizer significantly improved organic carbon, available N, P and K in soil under potato-maize-potato crop rotation (Kamlakumari and Singaram, 1996).

Hundekar *et al*. (1997) observed that application of FYM in combination of NPK increased the organic carbon and N, P and K content of soil. The application of FYM along with recommended dose of N, P and K increased the content of available N, P and K by 17.66, 3.33 and 8.0 %, respectively over N, P and K dose only. Further, Sharma and Gupta (1998) noted that combined application of organic manure and inorganic fertilizer significantly increased organic carbon, available nitrogen and phosphorus in the soil.

Integrated use of inorganic fertilizer along with FYM not only makes higher yields possible, thus providing greater yield stability (Vaidya and Gabhane, 1998). Sawarup and Yaduvanshi (2000) reported that application of green manure or FYM in combination with 100 per cent NPK significantly improved soil organic carbon, available N, P and K status of soil as compared to 150 per cent NPK only.

Santhy *et al*. (2001) reported that content of humic acid and fulvic acid in the soil increased with increasing levels of fertilizer application 50 to 150 per cent NPK along with FYM. Further, they observed significantly higher carbon content by application of 100% NPK with 10 t FYM ha^{-1}.

2.4 EFFECT OF BIOFERTILIZERS

2.4.1 Effect of *Azotobacter*

2.4.1.1 Growth parameters

Patel *et al*. (1992) reported that *Azotobacter* inoculation in Sorghum was brought about a significant increase in plant height as compared to no inoculation. They further noted that significant increase in dry matter accumulation of maize (34.65 per cent) by seed inoculation with *Azotobacter* over no inoculation (70.79 q ha^{-1}).

At Palampur, Rohitasva *et al*. (1993) observed significant increase in dry matter production in maize with *Azotobacter* inoculation (7.6 per cent) as compared to no inoculation (67.9 q ha^{-1}). Gandotra *et al*. (1998) reported that basal application of N with seed inoculation by *Azotobacter* in maize produced significant increase in all growth characteristics and plant biomass over no inoculation.

On the basis of pot culture experiment conducted by Yadav *et al*. (2000) observed significant effect of *Azotobacter* on wheat, he reported that plant height and biomass yield increased significantly by inoculation with *Azotobacter* strain with and without nitrogen over no inoculation. Sushila and Gajendra (2000) reported that significantly increased plant height, number of tillers m^{-1} row length and growth characters by seed inoculation with *Azotobacter* over seed inoculation with *Azospirillum* in wheat.

Field experiment conducted on sandy loam soils at Ludhiana (Punjab) studied that maize seed inoculation by *Azotobacter* or *Azospirillum* could not improve dry matter production (Chela, *et al*., 1993). But, Kulhari *et al*. (1998) observed during the study on sandy loam soils at Udaipur that seed inoculation with *Azotobacter* brought about significant increase in plant height at harvest (3.85 per cent) LAI (13.21 per cent) and dry matter $plant^{-1}$ (5.64 per cent) as compared to no inoculation (129.75 cm, 3.26 and 109.63 g, respectively).

2.4.1.2 Yield attributes and yield

Researchers carried out research under dryland conditions indicated the possibility of reducing nitrogen fertilizer application by inoculating the crop with appropriate strain of *Azotobacter* (Wani, 1990; Tilak and Singh, 1994). Jagtap and Shingate (1982) reported that inoculation of seed with *Azotobacter* increased 5 per cent grain yield of wheat over no inoculation.

Inoculation of maize seed with *Azotobacter* improved the grain yield from 27 to 72 per cent, at four locations by Shinde and Apte (1982) and Konde and Sindhe (1986). But Patil and Patil (1984) reported that successive increase in nitrogen level along with *Azotobacter* inoculation in cotton and save nitrogen up to 50 per cent over low to sub-optimal dose. While, Qureshi (1985) not observe any significant effect on grain yield of maize and wheat by *Azotobacter* inoculation.

Dhillon *et al*. (1980) reported an increase in wheat yield by seed inoculation with *Azotobacter* and save 30 to 50 per cent of the inorganic fertilizer over inoculation at sub optimal doses of nitrogen. Similarly, *Azotobacter* inoculation increased grain yield of wheat and saved 30-50 per cent of the inorganic fertilizer (Zambre, *et al*., 1984).

Seed inoculation of wheat through *Azotobacter* increased grain yield significantly and gave 1.4 q ha^{-1} additional grain yield over no inoculation (Sharma and Mishra, 1986). Lakshminaryan *et al*. (1992) observed that seed inoculation of wheat seed through *Azotobacter* significantly increased the grain and straw yields as compared to no inoculation.

Patil *et al*. (1992) reported that inoculation of maize seed through *Azotobacter* significantly increased 16 per cent in green fodder yield over no inoculation. Tyagi *et al*. (1993) reported that *Azotobacter* inoculation significantly increased the grain yield of various crops but highest yield was recorded in maize. Mishra *et al*. (1995) reported that *Azotobacter* inoculation significantly increased grains cob^{-1}, 1000-grain weight and grain yield of maize by 2.2, 19.3 and 28.5 per cent, respectively over no inoculation (23.10 g, 191 g and 16.8 q ha^{-1}), respectively.

Verma (1996) reported a significant increase in heads $plant^{-1}$, grain and stover yields of pearl millet by 12.7, 11.03 and 6.21 per cent with *Azotobacter* inoculation as compared to no inoculation (1.02, 10.24 and 48.62 q ha^{-1}, respectively).

Singh *et al*. (1999) while working at Udaipur observed significant increase in grain yield of wheat crop from 48.1 to 50.1 q ha^{-1} with *Azotobacter* inoculation over no inoculation. Kumar *et al.* (2001) reported significant increase in grain and straw yield by 12.6 and 1.4 per cent over control, respectively.

Sushila and Giri (2000) reported that both *Azotobacter* and *Azospirillum* separately improve the wheat grain yield by 11.0 and 13.6 per cent, respectively of wheat over no inoculation. Inoculation with *Azotobacter* significantly enhanced the grain yield of wheat over no inoculation (Prasad *et al*., 2001).

On sandy loam soils experiment was conducted by Singh and Singh (2002) at Agra, on *Azotobacter* reported that inoculation markedly increase both grain and straw yields of wheat by 6.14 and 5.26 per cent, respectively over no inoculation (19.4 and 54.35 q ha^{-1}, respectively). Similarly, on sandy clay loam soils at Udaipur, seed inoculation with *Azotobacter* brought significant increased in yield attributing characters and yield of maize *viz*. cob length, grains row^{-1}, 100 grain weight and grain yield (3.58, 5.36, 3.0 and 8.91 per cent, respectively) over no inoculation (Kulahari *et al*., 1998).

2.4.1.3 Nutrient content and uptake

Seed inoculation of maize by *Azotobacter* significantly increased nitrogen content and uptake over no inoculation (Saric *et al*., 1987). Similarly, Paredes *et al*. (1988) reported that *Azospirillum* inoculation of maize seedlings significantly increased total nitrogen content by 101 per cent over no inoculation. Wani (1988) also reported that pearl millet seed inoculation with *Azotobacter* significantly increased total N uptake over no inoculation.

Das *et al*. (1997) observed that *Azotobacter* inoculation in sorghum increased N, P and K content by 4.4, 5.8 and 3.1 per cent, respectively as compared to no inoculation (0.91, 0.17 and 0.64 per cent, respectively). Similarly, Jat (1998) also observed that *Azotobacter* inoculation increased N and P uptake by 5.2 and 5.5 per cent, respectively as compared to control (114.1 and 25.02 kg ha^{-1}, respectively).

Jain and Sharma (2001) reported that significant increase in total N, P and K uptake by 15.46, 10.69 and 11.23 per cent, respectively in maize with *Azotobacter* inoculation over no inoculation (109.21, 31.42 and 133.01 kg ha^{-1}, respectively). But, Goel and Somani (2002) informed that *Azotobacter* inoculation did not produce significant improvement in N, P and K content in maize over no inoculation.

2.4.2 Combined effect of *Azotobacter* and phosphorus solubilizing bacteria

2.4.2.1 Growth parameters

Ocampo *et al*. (1975) reported that *Azotobacter* and PSB inoculation of seedlings produced higher growth. Kundu and Gaur (1980) observed that *Azotobacter* population increased 3 to 4 fold in rhizosphere of wheat plants in combination with PSB but inoculation by *Azotobacter* only declined the population of *Azotobacter* after 7^{th} week of plant growth.

Tilak and Annapurna (1993) reported that combined inoculation of N fixing and P solubilising bacteria produced better growth of barley plants. Patidar (2000) recorded 10.7 per cent increase in LAI of sorghum plants with combined inoculation of *Azotobacter* and PSB as compared to no inoculation (3.99).

Jat (1998) reported 10.38 and 6.63 per cent increase in number of green leaves $plant^{-1}$ and LAI, respectively by combined inoculation of *Azotobacter* along with PSB as compared to no inoculation (9.44 and 1.43, respectively).

Jain and Sharma (2001) reported that combined inoculation of *Azotobacter* along with PSB significantly increased dry matter production of maize at 30, 60, 90 and at harvest by

4.68, 14.10, 9.87 and 15.18 per cent, respectively over no-inoculation (8.12, 42.97, 149.95 and 155.22 q plant^{-1}). Further, they also observed significant increase in LAI 9.01 per cent as compared to control (2.33). In a field experiment, Sawarkar (2003) observed a significant increase in plant height of maize by combined inoculation of *Azotobacter* and PSB over no inoculation.

2.4.2.2 Yield attributes and yield

Kundu and Gaur (1984) reported that inoculation by *Azotobacter* in combination with PSB increased grain yield of wheat over no inoculation. Jat (1998) reported that seed inoculation with *Azotobacter* + PSB did not affect significantly 1000-seed weight of sorghum. Sawarkar (2002) reported 3 q ha^{-1} more grain yield of maize with combined inoculation of *Azotobacter* + PSB which was significantly higher over no inoculation.

A field experiment conducted at Udaipur, significantly increased grain and stover yield of chickpea due to inoculation with N fixing bacteria with PSB over no inoculation (Jain and Singh, 2003). During 1998-2001 at four different location of Tikamgarh (M.P.), seed inoculation with 20 g *Azotobacter* + 20 g PSB kg^{-1} seed of wheat crop produced significantly higher grain yield (23 per cent) over farmer’s practices (Tomar *et al*., 2003).

2.4.2.3 Nutrient content and uptake

Kundu and Gaur (1982) reported the positive response of wheat crop to single and combined inoculation with phosphobacteria and *Azotobacter chroococcm* on the nutrient uptake. Mehta (1991) recorded that combined inoculation of *Azotobacte*r + PSB in maize significantly increased N content by 13.3 and 4.8 per cent in grain and stover, respectively over control. Patidar and Mali (2002) reported that inoculation of sorghum by *Azotobacter* along with PSB increased total N and P uptake by 10.7 and 7.4 per cent over control (125.05 and 39.25 kg ha^{-1}).

Jain and Sharma (2001) informed that combined inoculation of *Azotobacter* + PSB increased significantly N, P and K uptake in grain and stover by 24.84, 20.6, 17.13 per cent and 14.92, 16.86, 17.13 per cent, respectively, over no inoculation (73.02, 16.89,16.87 in grain and 36.20, 14.53, 116.10 kg ha^{-1} in straw, respectively). Similarly, Goel and Somani (2002) indicated total uptake of NPK increase by14.72, 17.24 and 10.98 per cent, respectively over control (117.68, 23.43 and 118.89 kg ha^{-1}, respectively) by combined inoculation with *Azotobacter* + PSB but it was at par with *Azotobacter* inoculation alone.

2.5.1 Growth parameters

Kundu and Gaur (1980) reported that in presence of FYM along with mixed inoculation (*Azotobacter* + PSB), *Azotobacter* population increased in rhizosphere of wheat plants. In a field trial, Gill *et al*. (2002) estimated significantly greater accumulation of dry matter due to better crop growth with different organic sources (FYM, poultry manure and bionema) + 50% recommended dose of NPK + *Azotobacter* in maize.

Sawarkar (2003) observed a significant increase in plant height of maize with 50% recommended dose of NPK fertilizer + *Azotobacter* + PSB as soil application @2kg ha^{-1}. Combined use of organic manures, biofertilizers and chemical fertilizers has been found to be promising not only in maintaining higher productivity but also in providing stable crop yield (Nambiar and Abrol, 1989).

2.5.2 Yield and yield attributes

In a field trial at Indore, combined use of NPK + *Azotobactor* + VAM + PSB increased grain yield of maize by 25 per cent as compared to NPK alone (Mishra *et al*., 1995).

Gill *et al.* (2002) estimated that combined application of 50 per cent recommended dose of NPK + *Azotobacter* + bionema in maize at Allahabad , significantly increased number of cobs $plant^{-1}$, grain cob^{-1}, 100-grain weight, grain yield (60 per cent higher) and harvest index as compared to 100 per cent recommended dose of NPK alone. Similarly, Sawarkar (2003) observed that combined application of 50 per cent recommended dose of NPK along with *Azotobacter* + PSB enhanced maize grain yield 10 q ha^{-1} over control. Further he reported that application of 50 percent recommended dose of NPK + *Azotobacter* + PSB as soil application @ 2 kg ha^{-1} significantly increased cob size, cob length, test weight of grain in maize. On sandy loam soil during 1999-2000 at Faizabad (U.P.) revealed, that inoculation through *Azotobacter* along with 75 and 100 per cent dose of NPK + 10 t FYM ha^{-1} in mustard enhanced grain yield by 31.8 and 38.2 per cent, respectively (Shankar *et al*., 2002). Similar trend was also noticed in improvement of seed and stover yield of mustard (Tomer *et al*., 1992). Similarly, Tomar *at al*. (2003) observed that combined application of NPK + *Azotobacter* + PSB in wheat produced significantly higher grain yield (77 per cent) over farmer's practice.

2.5.3 Nutrient content and uptake

Singh and Singh (2002) reported that combined application of 5 and 10 t FYM ha^{-1} + *Azotobacter* and increasing dose of nitrogen significantly increased N, P and K uptake by 6.35, 11.8 and 5.99 per cent, respectively in wheat over control. Similarly, Jat and Totawat

(2002) concluded that application of 100 per cent NP, 10 t FYM ha^{-1} and combined inoculation of *Azotobacer* +PSB significantly increased uptake of N by (83.28, 23.48, 11.37 per cent) P (71.06, 29.56, 11.87 per cent) and K (66.92, 16.93, 7.74 per cent) over their controls, respectively.

2.5.4 Protein content

Mishra *et al.* (2002) reported that combined application of 6 t FYM ha^{-1} + 75% recommended dose of NPK increased protein yield in maize but it was lower as compared to 100% NPK. Jain and Singh (2003) reported significantly increase in protein content 6.73 and 9.84 per cent with inoculation of N_2 fixing bacteria alone and with PSB combination over no inoculation in chick pea seeds.

2.5.5 B:C ratio and net return

Mishra *et al.* (1995) recorded maximum net return Rs.18804 ha^{-1} with 100% NPK followed by Rs 15410 ha^{-1} with 6 t FYM ha^{-1} + 75% NPK and B:C ratio obtained was 2.73 and 2.40, respectively as compared to control (Negative net returns and B:C ratio obtained by Rs. 1978 t ha^{-1} and0.21, respectively).

Suri *et al*. (1996) reported that application of 5 t FYMha^{-1} + recommended dose of NPK gave 22 per cent higher net return as compared to no FYM.

During three years study at Gayeshpur, West Bengal, results reveals that combined application of 10 t FYM ha^{-1} + 75% recommended NPK gave highest net return in fodder based oat, maize and sorghum cropping system (Nanda *et al*., 1998). Similarly, Chandrashekara *et al*. (2000) observed that application of 10 t poultry manure ha^{-1}along with 100 per cent recommended dose + NPK in maize crop resulted in higher net return (Rs 6675 ha^{-1} and benefit: cost ratio (1.51). Verma *et al.* (2002) observed that application of 50% N though fertilizer + 50% through FYM recorded significantly higher net return Rs 31,167 ha^{-1} in wheat during rabi and Rs. 13,257 ha^{-1} in maize (fodder) during *kharif* over rest of the treatments. Deshveer *et al*. (2002) reported that application 60% NP through fertilizer + 40% N through FYM gave highest net return and B: C ratio (5.92) as compared to rest of the treatment.

3. MATERIALS AND METHODS

A field experiment entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** was conducted during K*harif* season for two consecutive years 2001 and 2002. The details of experimental techniques, materials used and criteria adopted for treatment evaluation during the course of investigation are presented in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

The site is situated at south-east part of Rajasthan at an elevation of 463.6 m above mean sea level with latitude of 24^o 20' N and longitude of 74^o 40' E. Alfisols are the predominant soils in Bhilwara covering more than 50 per cent land area with undulating topography. The soils are shallow in depth with dense sub surface layer. Structural instability and rapid surface sealing by crusting enhances surface runoff. Heavy showers during rainy season cause excessive runoff and loss of soil and nutrients, particularly on sloppy land of south eastern part of Rajasthan. Further, soil erosion affects the physical, chemical and biological make-up of the soil leading to low crop productivity. This part of Rajasthan is well known to grow maize (30.6 per cent area) which requires well drained soils and some degree of slope is beneficial for its optimum growth and development of crop.

The experiment was conducted at the Instructional Farm, Khrishi Vigyan Kendra, Bhilwara. At instructional farm there are an open well is situated with limited water by which 1-2 ha area may be irrigated once or twice as per availability of water. Under these situations only *kharif* crops grown but some times *rabi* crops also taken if abundant rainfall received with normal withdrawal of monsoon which leave sufficient conserved moisture for growing of *rabi* crops.

3.1.1 Physico-chemical properties of soil

The soil samples were randomly drawn from five different spots from the experimental field at 0 to 30 cm depth before sowing of experiment during each year and composite sample was prepared after proper mixing, grinding, drying and passing through 2 mm sieve. The composite soil sample was analysed to determine the physico-chemical properties of soil. The data on physico-chemical properties of soil for both the years of the study are presented in Table 3.1 alongwith the methods used for analysis. The soil analysis indicated that soils of the experimental field were sandy clay loam in texture and alkaline in reaction (8.14 and 8.10 pH during 2001 and 2002, respectively). The soils were poor in organic matter while low in available nitrogen (253.8 and 261.7 kg ha^{-1}) and medium in available phosphorus (21.2 and 22.2 kg P_2O_5 ha^{-1}) but high in available potassium (343.4 and 346.3 kg ha^{-1}) during the years 2001 and 2002, respectively.

Table 3.1 Physico-chemical properties of the experimental soil

Properties	**Value**		**Reference**
	2001	**2002**	
A Mechanical Composition			
Sand (%)	56.4	56.1	Hydrometer method (Bouyoucos, 1962)
Silt (%)	20.2	20.4	
Clay (%)	23.4	23.5	
Texture class	Sandy clay loam	Sandy clay loam	Triangular diagram (Brady, 1983)
B. Physical Properties			
Bulk density (mgm^{-3})	1.39	1.41	Core sampler method (Piper, 1950)
Particle density (mg m^{-3})	2.61	2.58	Black (1965)
Porosity (%)	47.23	46.54	Black (1965)
C. Chemical Properties			
Organic carbon (%)	0.375	0.392	Rapid titration method (Walkely and Black, 1947)
Organic matter (%)	0.646	0.675	
Available nitrogen (kg ha^{-1})	253.8	261.7	Alkaline $KMnO_4$ method Subbiah and Asija, 1965)
Available phosphorus (kg P_2O_5 ha^{-1})	21.2	22.2	Olsen's method (Olsen *et al.*, 1954)
Available potassium (kg K_2O ha^{-1})	343.4	346.3	Flame photometer (Richards, 1968)
E.C. (dSm^{-1} at 25 °C) (1:2.5 soil water suspension)	0.22	0.20	Conductivity bridge method (Richards, 1968)
Soil pH (1:2.5 soil water suspension)	8.14	8.10	pH meter (Richards, 1968)

3.1.2 Climate and weather

Annual rainfall of Bhilwara is 657.5 mm distributed over 27 rainy days. About 614.5 mm rainfall received during monsoon season extending 27^{th} to 37^{th} standard week. The mean duration of monsoon is about 84 days. The PET is 1681.5 mm while PET during *kharif* (June to September) is 604.5 mm. The mean sunshine hours are maximum 11.75 hr day^{-1} in April while, minimum is 4.27 hr day^{-1} in August. The mean sunshine hours decrease from April to August.

The meteorological observation recorded at Dryland Farming Research Station, Arjia, Bhilwara during cropping periods are presented in Appendix II and I and depicted in Fig 3.1. and 3.2. Minimum and maximum temperatures during crop growth period ranged between 18.9 to 37.3 ^{0}C and 18.9 to 40.2 ^{0}C during 2001 and 2002, respectively. During crop growth period, 668.4 mm and 224.9 mm rainfall were recorded in 2001 and 2002, respectively. However, the distribution of rainfall varied in both seasons, only 33.64 per cent rainfall was received during 2002 as compared to 2001 and there were long dry spells occurred during initial crop growth stage 2^{nd} to 28^{th}, July 2002 and grain filling stage 10^{th} September to 4^{th} October, 2002. The minimum and maximum range of sunshine hours were between 0.0 to 8.9 and 2.1 to 9.4 hr day^{-1}, pan evaporation between 0.9 to 6.3 and 4.1 to 12.3 mm day^{-1}, were measured during 2001 and 2002, respectively.

3.2 CROPPING HISTORY

Experimental fields have been used for growing field crops from last several years. During both the years, experimental crop was sown in separate field at KVK Bhilwara. Last five years cropping history of experimental fields are given in Table 3.2.

Table 3.2 Cropping history of experimental site

Year	Experimental field (2001)		Experimental field (2002)	
	Kharif	***Rabi***	***Kharif***	***Rabi***
1997	Maize	Fallow	Maize	Fallow
1998	Black gram	Fallow	Black gram	Fallow
1999	Black gram	Gram	Maize	Fallow
2000	Black gram	Gram	Maize	Fallow
2001	Maize *	Fallow	Black gram	Fallow
2002	-	-	Maize *	-

***Experimental crop**

3.3 DETAILS OF EXPERIMENTS

The experiment entitled "Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan" consisted 30 treatments. The experiment was proposed to consist 10 treatments in main plot [three treatments of FYM (Farm Yard Manure), three treatments of NPK along with one main plot control] and three treatments in subplot. The details of treatments along with their symbols are given below:

3.3.1 Treatment details

Main plot:

(A)	**Main plot control**	C_0
(B)	**Organic manures (FYM)**	
(i)	Control (No FYM)	M_0
(ii)	5 tonne ha^{-1}	M_1
(iii)	10 tonne ha^{-1}	M_2
(C)	**Chemical Fertilizers (NPK)***	
(i)	50% RDF	F_1
(ii)	75% RDF	F_2
(iii)	100% RDF	F_3

Main plot treatments combination: 10 (3 O. M. x 3 Chem. Fert + 1 control)

Sub plot:

(D)	**Bio fertilizers**	
(i)	Control (No inoculation)	B_0
(ii)	*Azotobacter*	B_1
(iii)	*Azotobacter* + PSB	B_2

3.3.2 Other treatment details:

No. of treatment combinations	–	10 × 3 = 30
Design	–	SPD
Replications	–	3
Plot size		
Gross	–	5.0 m × 4.8 m
Net	–	4.0 m × 3.6 m

*NPK fertilizer dose kg ha^{-1} :

N P2O5 K2O

1.	50% RDF	45.0	15.0	15.0
2.	75% RDF	67.5	22.5	22.5
3.	100% RDF	90.0	30.0	30.0

*Recommended dose of N, P and K were as per the recommendation for maize crop in the Zone IVa i.e. 90 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}.

3.3.3 Experimental design and layout

The experiment comprised 30 treatment combinations, which were replicated three times and laid out in split plot design. The plan of layout is shown in fig. 3.3.

3.4 DETAIL OF CROP RAISING

3.4.1 Maize

3.4.1.1 Varity: Navjot

Maize composite 'Navjot' having yellow orange semi-flint seeds and of medium maturity was used as test variety. It was released from Punjab Agricultural University, Ludhiana in 1982. It is developed from intra-population improvement in advanced generation of the cross Partap (J-54) x Tarun. Plant height is 190 cm with relatively low ear placement (70 cm). Stem thick and strong, relatively less leafy, leaves of medium length, cob are medium size with well developed husk cover, tassels relatively small, kernels of medium size, mostly flint and orange yellow in colour. It possesses distinctly better disease resistant than local with respect to leaf blight, stripe downy mildew, Philippine downy mildew, late wilt and bacterial stalk rot.

3.4.1.2 Field preparation

After receiving pre-monsoon shower in the 2nd week of June the experimental field was prepared by ploughing once with tractor drawn disc plough followed by cultivator along with planking during both the years of experimentation.

3.4.1.3 FYM application

As per treatment well-decomposed FYM was broadcasted and incorporated in the respective plots 21 days before sowing. The nutrient composition of FYM is given in Table 3.3.

Table 3.3 Composition of FYM on oven dry basis

Nutrient content (%)	Year	
	2001	**2002**
N	0.47	0.51
P_2O_5	0.24	0.26
K_2O	0.51	0.52

3.4.1.4 Fertilizer application

(a) **Nitrogen:** 50, 75 and 100 per cent of recommended dose (90 kg ha^{-1}) of nitrogen was applied through diammonium phosphate and urea. The nitrogen applied through diammonium phosphate was subtracted from the nitrogen dose and remaining nitrogen was applied through urea in two equal splits one at knee high (30 DAS) and another at silking stage (50 DAS) as per treatment.

(b) **Phosphorus:** As per treatment, 50, 75 and 100 per cent of the recommended dose (30 kg ha^{-1}) full quantity of phosphorus was applied through diammonium phosphate (DAP) at the time of sowing in furrows behind the plough below the seeds.

(c) **Potash:** As per treatment the whole quantity of potash i.e., 50, 75 and 100 percent of recommend dose (30 kg ha^{-1}) was applied through murate of potash at the time of sowing in furrows behind the plough below the seeds.

3.4.1.5 Seed and seed treatment

(a) **Quantity of seed:** For sowing, 30 kg seed ha^{-1} was used. Seed was treated with particular strains of bacteria as per treatment and small packets were weighed for each plot to obtain uniform plant stand. The seed requirement for each plot was 72 g so the total seed requirement for all experimental area was: 72 g × 90 = 6.480 kg

(b) **Germination test:** The germination of seed was determined by sowing them in peteri dishes containing moist filter papers under normal conditions. After germination the germinated seeds were counted and computed in percentage. It was found 87 per cent.

(c) **Seed inoculation:** The specific culture of *Azotobacter* and PSB obtained from the Department of Agriculture Chemistry and Soil Science, Rajasthan College of Agriculture, Udaipur. For inoculation of seed, 10 per cent sugar solution was prepared and it was boiled, cooled and sprinkled on the seed. The *Azotobacter* culture was broadcast uniformly over the sticker-coated seeds at the rate of 20 g kg^{-1} of seed and mixed thoroughly. Same procedure was adopted for inoculation of seed with PSB.

(a) Sowing of seed

After seedbed preparations, maize variety 'Navjot' was sown on July 05th and July 02nd during 2001 and 2002, respectively. Seeds were sown at 5-6 cm depth in furrows keeping row spacing of 60 cm, Furrows were opened through deshi plough and treated seeds were sown as per treatment in separate plots manually with the help of 'Pora'.

3.4.1.6 Thinning

In order to maintain plant population thinning was done at 25 cm apart after 15 days of sowing

3.4.1.7 Inter culture operations

The intercultural operations were performed twice at 20 DAS and 35 DAS for better aeration and removal of the weeds. The name of some important weeds presented in the experimental plots were *Echinochloa colonum*, *Echinochloa crusgulli*, C*ynodon dactylon, Cyprus rotundus*, *Amaranthus virdis*, *Solanum nigrum* and *Phylanthus niruri* etc. The detail of cultural operation and treatment application was given in Table 3.6.

Table 3.4 Details of cultural operations and treatment application carried out during the course of experimentation

S. No.	Operations	2001	2002

1.	Field preparation	13.6.2001	9.6.2002
2.	Layout and bunding	14.6.2001	10.6.2002
3.	FYM incorporation	14.6.2001	10.6.2002
4.	Final layout	5.7.2001	2.7.2002
5.	Fertilizer placement and sowing	5.7.2001	2.7.2002
6.	Thinning	20.7.2001	17.7.2002
7.	Interculture operations (20 DAS)	25.7.2001	22.7.2002
8.	Plant Protection spray (Endosulfan)	26.7.2001	23.7.2002
9.	Inter culture operation (35 DAS)	10.8.2001	7.8.2002
10.	Top dressing of urea		
11.	30 DAS	6.8.2001	3.8.2002
12.	50 DAS	26.8.2001	23.8.2002
13.	Supplemental irrigation	4.9.2001	8.9.2002
14.	Harvesting	8.10.2001	4.10.2002
15.	Threshing	20.10.2001	17.10.2002

3.4.1.8 Irrigation

During both years only one supplemental irrigation was given at grain filling stage for successful crop production. The details about the irrigation given have been mentioned in Table 3.4.

3.4.1.9 Plant protection

Only one spray of endosulphan 35 EC (0.1 per cent) was carried out against stem borer at 20 DAS both the years.

3.4.1.10 Harvesting

The net plots were harvest after attending physiological maturity (leaves turn golden yellow) with the help of sickles along with cobs close to the ground. The net plot was harvested by leaving one row on both side (length wise) and 0.5 m on both the sides (width wise) in each plot. The harvested produce of each net plot was bundled and properly tagged for treatment evaluation. These bundles were left open for sun drying for few days.

3.4.1. 11Threshing

After sun drying of harvested plants of net plot area, cobs were separated out from individual plant. After separation of the cobs from plants, they were de-husked and shelled through beating the cobs in gunny begs and produce of each plot was winnowed and weighed.

3.5 TREATMENT EVALUATION

Following criteria were adopted for evaluating the effect of the treatments.

3.5.1 Growth studies

(a) **Plant population at 20 DAS and at harvest:** Number of plants in each net plot were counted after final thinning (20 DAS) and at harvest. The population was expressed on hectare basis (1000 ha^{-1})

(b) **Plant height:** At harvest five plants were randomly selected and tagged from each net plot. Height of tagged plants was measured from ground level to the top of shoot. The height was calculated and expressed in cm.

(c) **Dry matter accumulation:** Five randomly selected plants from each plot were removed at 30, 50, 70 DAS and at harvest. These plants were chopped with the help of bill-hook and sun dried for two days and then oven dried at 65 ^{o}C till a constant weight was recorded. Dry matter accumulation expressed in g $plant^{-1}$ after calculating the average weight.

(d) **Leaf Area Index (LAI):** For maize, the length and maximum width of every viable leaf of five plants were measured at 30, 50, 70 DAS and at harvest with the help of meter scale and then leaf area was worked out by formulae as proposed by Montgomery (1911).

Leaf area = Length × Maximum width × 0.75

The average was worked out and values of leaf area were expressed in cm^2 $plant^{-1}$ and used for computing the leaf area index. From the leaf area $plant^{-1}$, the leaf area index (LAI) was worked out for maize crop by multiplying the leaf area $plant^{-1}$ with the number of plants in the net plot area and dividing it by net plot area as per method given below.

$$\text{LAI} = \frac{\text{Leaf area plant}^{-1}\ (\text{cm}^2)\ \text{x No. of plants in net plot}}{\text{Net plot area (m}^2)\ \text{x}\ 10^4}$$

(e) **Crop growth rate (CGR):** The rate of increase in dry matter per unit area per unit time dry matter measured in g/m^2/day.

$$\text{CGR (g/m}^2\text{/day)} = \frac{W_2 - W_1}{t_2 - t_1} \text{ x } \frac{1}{P}$$

Where,

W_1 and W_2 are dry weight of plant and at time t_1 and t_2, respectively.

P represents the ground area.

(f) **Net assimilation rate (NAR) :** Rate of increase in dry weight of plant per unit leaf area per unit time and calculated by the following formulas given by Red Ford (1967)

$$\text{NAR (g/m}^2\text{/day)} = \frac{W_2 - W_1\,(L_n L_2 - L_n L_1)}{t_2 - t_1\,(L_2 - L_1)}$$

Where,

W_1 and W_2 are dry weight of plant and L_1 and L_2 is LAI at time t_1 and t_2, respectively. P represents the ground area.

$L_n = Log_e = 2.303 \log_{10}$ of L_2 and L_1

(g) **Leaf area duration (LAD):** It is expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth. It reflects the extent or seasonal integral of light interception and correlate highly with yield. It is usually express in day or weeks. It is computed by the formula given by Hunt (1978).

$$\text{LAD}\,(\text{dm}^2\ \text{day}^{-1}) = \frac{(L_1 + L_2)\text{ x }(t_2 - t_1)}{2}$$

or integral mean valve of LAD calculated by following formula

$$\overline{\text{LAD}}\,(\text{dm}^2\ \text{day}^{-1}) = \frac{(L_1 + L_2)\text{ x }(t_2 - t_1)}{2} + - - - - + \frac{(L_{n-1} + L_n)\text{ x }(t_n - t_{n-1})}{2}$$

Where,

$\overline{\text{LAD}}$ (dm^2 day^{-1}) is mean value over time interval (t_2-t_1)

L_1 and L_2 is leaf area at time t_1 and t_2

L_n and L_{n-1} is leaf area at time t_n and t_{n-1}

Unit of LAD is Area x Time

3.5.2 Yield attributes

(a) **Number of cobs plant^{-1}:** Number of cobs of five tagged plants were counted at harvest and the mean value plant^{-1} under each experimental unit was worked out.

(b) **Number of grains cob^{-1}:** The randomly selected five cobs of net plot were taken for counting the number of grain cob^{-1} firstly count number of row in the individual cob and number of grain row^{-1} than multiply and their average were taken as number of grains cob^{-1}.

(c) **Weight of grain cob^{-1}:** The randomly selected five cobs of net plot taken for the weight of individual cob was shelled with hand sheller. The grains were weighted and average weight of grains cob^{-1} was computed and expressed as weight of grains cob^{-1} in grams.

(d) **Test weight:** The sun dried 1000 grains were counted for recording the test weight from each plot .

3.5.3 Yield

(a) **Grain yield:** Cobs were separated from the plants of net plot after proper sun drying, de-husked and shelled with the help of single cob sheller. The produce was cleaned, weighted and expressed in term of grain yield q ha^{-1}.

(b) **Stover yield:** Stover yield was obtained by subtracting the grain yield plot^{-1} from the respective biological yield plot^{-1} and finally expressed in term of stover yield (q ha^{-1}).

(c) **Biological yield:** The weight of thoroughly sun dried plants of net plot along with cobs were recorded and expressed as biological yield q ha^{-1}.

(d) **Harvest index:** It is the ratio of economic yield and biological yield and calculated as per formula given by Donald and Hamblin (1976)

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

3.5.4 Biochemical analysis

(a) **Nutrient content in plants:** Five randomly selected plant from each plot were removed at 30, 50 and 70 DAS for dry matter accumulation of same plants were used for nutrient content analysis. At harvest the grain and stover samples were kept from each plot and oven dried at constant temperature of 65 ^{o}C for 24 hours. The dried samples were finely grind and passed though 40 mm mesh sieve and used for determination of N, P and K content in grain and stover as per method furnished in Table 3.5 and expressed in per cent in dry matter

Table 3.5 Methods used for various chemical analysis of plant samples

Content	Method of analysis	Reference
Nitrogen	Nesselar's regent colori metric method	Snell and Snell (1949)
Phosphorus	Method No. 61,USDA Hand Book No. 60	Richards (1968)
Potassium	Flame photometer method	Jackson (1967)

(b) **Nutrient uptake:** The uptake of N, P and K at 30, 50, 70 DAS and at harvest by grain and stover were calculated as:

$$\text{Nutrient uptake by grain/stover (kg ha}^{-1}) = \frac{\text{Nutrient content in grain/stover (\%) x Dry matter / grain / stover yield (kg ha}^{-1})}{100}$$

(c) **Protein content in grain:** The protein content in grain was calculated by multiplying the percent nitrogen content in grain with factor 6.25 (A.O.A.C., 1960).

(d) **Total nutrient uptake:** The total nutrient uptake by crop was computed by summing up the uptake by both grain and stover at harvest.

3.5.5 Soil analysis

Soil samples were taken after harvest of maize crop from each experimental plot up to 15 cm depth with the help of *khurpi* from two points. These samples were sun dried and then crushed gently in wooden pestle and mortar and sieved through 2 mm sieve and analyzed for available NPK and organic matter (organic matter is estimated by multiplying organic carbon content to 1.724).

3.6 NUTRIENT BALANCE SHEET

Based on apparent gain on loss of nutrient, an attempt was made to establish fate of nutrient available in soil, added through different treatments and crop removals were dually taken into account during the course of maize crop for two consecutive years. The nutrient balance sheet was worked out as follows:

Expected nutrient balance (D) = (A+B) **-** C

Where,

A = Initial nutrient status of soil

B = Nutrient added as per treatment (Through FYM and fertilizer)

C = Nutrient taking by crop

Apparent gain /loss (F) = E - D

Where,

E = Actual nutrient balance i.e. the available nutrient status of soil after harvest of the crop

Actual gain / loss (G) = E – A

3.7 STATISTICAL ANALYSIS

The standard procedure as described by Gomez and Gomez (1984) were employed by applying the techniques of analysis of variance for split plot design “SPD” in order to test the significance of the experimental results. Wherever, “F” test was found significant at 5 per cent level of significance, the critical difference (CD) for treatment means were worked out. In order to establish relationship between various components, coefficient of correlation and regression equation were also computed.

3.8 ECONOMICS

In order to evaluate the effectiveness of different treatments and to ascertain the most remunerative treatment, economics of different treatment combination were worked out in terms of net return ha^{-1} and benefit cost ratio. The expenses incurred on cultivation operations from preparatory tillage to harvesting and threshing including cost of input *viz*. seed, fertilizer, FYM, plant protection chemicals applied to the experimental plot were computed and the cost of cultivation was thus worked out treatment wise.

4. EXPERIMENTAL RESULTS

The results of field experiment entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south east Rajasthan"** conducted at instructional farm, Krishi Vigyan Kendra, Bhilwara during the *kharif* 2001 and 2002 are presented in this chapter. Data pertaining to the effect of different treatments on growth, yield attributes, yields, nutrient contents and other aspects of the crop were statistically analysed in order to test the significance of the results. Data for all the main effects and significant interaction effects are presented in this chapter. The analyses of variance for different components are given in Appendix III to XXVI.

4.1 EFFECT OF ORGANIC MANURE, FERTILIZER AND BIO FERTILIZER ON GROWTH CHARACTERS

4.1.1 Plant Population

Control Vs Rest

Data presented in table 4.1 and their analysis of variance given in appendix III reveal that the application of treatments did not influence the plant population significantly over control at 20 DAS and at harvest during both the years.

Farm yard manure

Application of different levels of FYM were failed to show any significant response on plant population at both the stages i.e. 20 DAS and at harvest during either year of experimentation.

Fertilizer levels

Increasing levels of fertilizers from 50 to 100 per cent RDF did not affect the plant population at 20DAS and at harvest stage during course of study.

Biofertilizers

Biofertilizers also could not affect the plant population significantly at 20 DAS and at harvest during 2001 and 2002.

4.1.2. Plant height

Control Vs Rest

An assessment of data presented in Table 4.2 and their analysis of variance given in Appendix III show that application of treatments significantly increased the plant height over control during either year of experimentation. On mean basis, treatment application increased plant height by 18.14 per cent over control.

Farm yard manure

Data in Table 4.2 indicate that application of 10 t FYM ha^{-1} significantly increased plant height over control during both the years. While, non-significant differences were observed between 0 and 5 t FYM ha^{-1} during 2001 and 2002. Further, 10 t FYM ha^{-1} significantly improved plant height over lower doses during 2002. On mean result basis, 10 t FYM ha^{-1} increased the plant height by 10.27 and 5.74 per cent over control and 5 t FYM ha^{-1}, respectively.

Fertilizer levels

Further, data show that application of fertilizers increased the plant height with increasing level of fertilizers while, 100% RDF showed significant variation over 50% RDF but at par with 75% RDF during both the years. On mean data basis, increase in plant height was noted by 8.17 and 5.70 per cent with 100 and 75% RDF over 50% RDF, respectively.

Biofertilizers

Seed inoculation with bio-fertilizers significantly enhanced the plant height over no inoculation. However, combined inoculation with *Azotobacter* + PSB gave maximum plant height but found at par with *Azotobacter* alone during both the years. On mean result basis, plant height was increased by 6.07 and 5.19 per cent with *Azotobacter* + PSB and *Azotobacter* alone over no inoculation, respectively.

4.1.3 Dry matter accumulation

Control Vs Rest

An appraisal of data presented in Table 4.3 and their analysis of variance given in Appendix IV indicate that application of treatment enhanced significantly DMA $plant^{-1}$ at all successive crop growth stages from 30 days to harvest over control during either year of study. Two years mean data show that DMA $plant^{-1}$ increased by 60.57, 57.18, 44.26 and 51.36 per cent with application of treatment at 30,50,70 DAS and at harvest over their controls, respectively.

Farm yard manure

Dry matter accumulation plant^{-1} increased at a faster rate up to 50 DAS of crop growth stage and thereafter increase in dry matter was not quantum as between 50 DAS to harvest. Critical study of the data reveal that 10 t FYM ha^{-1} significantly improved the DMA plant^{-1} over no FYM and 5 t FYM ha^{-1} at all successive crop growth stages during both the years except at harvest with 5 t FYM ha^{-1} during first year of experimentation. Further, data indicated that non-significant difference between 0 and 5 t FYM ha^{-1} at all successive crop growth stages during course of study except during 2002 at 30 DAS and at harvest during 2001 where, 5 t FYM ha^{-1} registered their superiority over no FYM. On two years mean basis, increase in DMA plant^{-1} at 30, 50, 70 DAS and harvest with 10 t FYM ha^{-1} were by 28.0, 22.35, 22.74 and 18.36 per cent over no FYM, respectively.

Fertility levels

Increasing levels of NPK enhanced the value of dry matter accumulation was more pronounced at 50 and 70 DAS stage of maize. However, application of 75% RDF produced significantly higher DMA plant^{-1} over 50% RDF but statistically at par with 100% RDF at all crop growth stages during both the years. Further, maximum dry matter plant^{-1} was recorded under 100 per cent RDF during the course of study. On mean result basis, application of 75 and 100 per cent RDF increased DMA plant^{-1} by 14.06, 14.11, 10.89, 9.47 per cent and 18.52, 18.78, 15.04, 12.90 per cent at 30,50,70 DAS and at harvest over 50 % RDF, respectively.

Biofertilizers

Seed inoculation with bio fertilizers significantly enhanced the DMA plant^{-1} over no inoculation at all crop growth stages during both the years except at 50 DAS stage during 2002 where, *Azotobacter* treatment was found at par with no inoculation. While, difference between *Azotobacter* alone and combined inoculation of *Azotobacter* + PSB were founds at par with each other. However, combined inoculation with *Azotobacter* + PSB significantly increased DMA plant^{-1} over *Azotobacter* alone only at 50 DAS during 2001. Although, inoculation of *Azotobacter* alone and no inoculation were found at par at 50 DAS during 2002. The mean data of two years reveal that combined inoculation of *Azotobacter* + PSB and *Azotobacter* alone increased in DMA plant^{-1}by 12.14, 14.34, 10.41, 9.03 and 9.10, 9.13, 7.65, 6.02 per cent at 30,50,70 DAS and harvest over no inoculation, respectively.

4.1.4 Leaf area index (LAI)

Control Vs Rest

It is explicit from data in Table 4.4 and their analysis of variances furnished in appendix V reveal that after initial leg phase i.e. 30 DAS to 50 DAS LAI increased rapidly and thereafter enhancement in LAI was not quantum as between 50 to 70 DAS. After 70 DAS, LAI was drastically decreased up to harvest. Further, data indicate that application of treatments significantly influenced the LAI at all successive stages of crop growth i.e. 30 DAS to harvest over control during both the year of investigation. The mean data of two years indicate that increased in LAI with treatment application in the tune of 29.86, 44.69, 36.55 and 44.83 per cent at 30,50,70 DAS and harvest over their controls, respectively.

Farm yard manure

Among the FYM levels, successive increment in FYM level up to 10 t ha^{-1} significantly enhanced the LAI over 0 and 5 t ha^{-1} at all successive crop growth stages during either year of investigation. While, at 30 DAS and harvest, difference between 5 and 10 t FYM ha^{-1} were statically at par with each other. On mean data basis, application of 10 t FYM ha^{-1} ha recorded highest value of LAI i.e. 1.105, 3.024, 3.529 and 1.918 at 30, 50, 70 DAS and harvest over their controls (0.929, 2.583, 3.036 and 1.625), respectively.

Fertilizer levels

Application of 100% RDF significantly improved the LAI over 50% RDF but at par with 75% RDF at all successive crop growth stages during both the years of investigation. While, application of 75% RDF also found significantly superior over 50% RDF at 50 and 70 DAS during both the years. However, application of 75% RDF significantly enhanced LAI at 50 and 70 DAS over 50% RDF in coupled of years of investigation. On the basis of mean results, application of 100% RDF increased the LAI by 13.65, 14.06, 15.15 and 12.85 percent at 30, 50, 70 DAS and harvest over 50% RDF, respectively.

Biofertilizers

It is evident from the data depicted in table 4.4 that combined seed inoculation with *Azotobacter* + PSB significantly increased LAI over no inoculation from 50 DAS to harvest stages whereas at 30 DAS none of the biofertilizers was found able to increase LAI significantly over control during both the years of experimentation. Further, combined inoculation with *Azotobacter* + PSB proved significantly superior at 50 DAS during 2001 and at harvest during 2002 over *Azotobacter* alone. Data again show that *Azotobacter* alone proved significantly superior over no inoculation at 50, 70 DAS and at harvest during 2002. On mean result basis, increases in LAI with combined inoculation of *Azotobacter* + PSB were by 5.05, 8.09 and 11.11 per cent at 50, 70 DAS and harvest, respectively over their controls.

4.1.5 Crop growth rate (CGR)

Control Vs Rest

An examination of data presented in Table 4.5 and analysis of variances furnished in Appendix VI reveal that the crop growth rate was very slow up to 30 DAS, whereas it was increased rapidly between 30-50 DAS and reach up to maximum value between 50-70 DAS. Thereafter, growth rate was slightly decreased between 70 DAS to harvest of crop during both the years. Application of treatment significantly influenced the crop growth rate at all the crop growth stages i.e. 30,50,70 DAS and at harvest over their controls. On the basis of two years mean results indicate that increases in crop growth rate with treatment application were by 59.93, 62.17, 41.79 and 61.02 per cent at 30,50,70 DAS and at harvest over their control, respectively.

Farm yard manure

Increasing levels of FYM markedly influenced crop growth rate of maize and it was reached up to maximum level between 50 to 70 DAS of crop growth during both the years. Application of 10 t FYM ha^{-1} significantly enhanced the crop growth rate at 0-30, 30-50 and 50-70 DAS of crop growth over no FYM but at 70 DAS to harvest variation between FYM levels were found non significant during both the years. Further, data show that difference between 5 and 10t FYM ha^{-1} were found significant at 0-30 DAS and 30-50 DAS during both years. However, difference between 0 and 5 t FYM ha^{-1} was non-significant at all crop growth stages during both the years except during 2002 between 0-30 DAS. The mean data of two years indicate that application of 10 t FYM ha^{-1} enhanced the crop growth rate between 0-30, 30-50, 50-70 DAS and 70 DAS to harvest by 29.72, 25.47, 23.28 and 13.35 per cent over no FYM, respectively.

Fertilizer levels

Application of 75% RDF significantly increased the crop growth rate at 0-30 DAS over 50% RDF during both years Further, data indicate that application of 100% RDF significantly enhanced the CGR over 50% RDF but differences between 75 and 100% RDF were non-significant at all successive crop growth stages. However, increasing dose of fertilizer failed to prove significant variation at 70 DAS to harvest. On mean basis, application of 100% RDF increased CGR at 0-30, 30-50, 50-70 DAS and 70 DAS to harvest by 19.28, 19.05, 15.34 and 9.77 per cent over their respective 50% RDF, respectively.

Biofertilizers

Crop growth rate significantly improved by seed inoculation either by *Azotobacter* alone or combined inoculation with *Azotobacter* + PSB over no inoculation at all growth stages except 70 DAS to harvest during either year of investigation. Further, data also indicate that difference between *Azotobacter* alone and combined inoculation of *Azotobacter* + PSB was non-significant except at 30-50 DAS during 2001. Data on two years mean basis. Indicated that value of CGR increases with combined inoculation of *Azotobacter* + PSB between 0-30, 30-50, 50-70 DAS and 70 DAS to harvest by 12.91, 16.03, 10.79, and 1.78 per cent over their respective no inoculation, respectively.

4.1.6 Net assimilation rate (NAR)

Control Vs Rest

An assessment of data presented in Table 4.6 and their analysis of variance given in Appendix VII show that application of treatment significantly increased the net assimilation rate over control during both the years. Two year mean data indicate that treatment application gave maximum values of NAR which were 22.90, 30.01 and 37.17 per cent higher between 30-50 DAS, 50-70 DAS and 70 DAS to harvest stages over control, respectively.

Farm yard manure

Increasing levels of FYM improved the net assimilation rate at different growth stages but did not reach up to the level of significance except between 50-70 DAS stage during both the years. However, at this stage i.e. 50-70 DAS 10 t FYM ha^{-1} registered a significant improvement in net assimilation rate over no FYM. While, difference between 0 to 5 and 5 to 10 t FYM ha^{-1} were non significant either year of experimentation. Data two years mean basis, 10 t FYM ha^{-1} enhanced NAR between 50-70 DAS by 12.75 per cent over no FYM (9.114).

Fertilizer levels

Among the fertilizers levels net assimilation rate could not reached up to significance level at any crop growth stage during both the years.

Biofertilizers

Seed inoculation with biofertilizers did not affect the net assimilation rate significantly at early and late stages of crop growth during either year of experimentation. While, net assimilation rate between 50-70 DAS showed significant variation with seed inoculation either *Azotobacter* alone or combination of *Azotobacter* +PSB during the study. Among the biofertilizers, *Azotobacter* + PSB proved significantly superior over *Azotobacter* alone during 2001 but in 2002 both the treatments were at par with each other. Mean data of two years indicate that combined seed inoculation of *Azotobatecr* + PSB improved NAR values between 50-70 DAS by 14.13 per cent over control (8.700).

4.1.7 Leaf area duration (dm^2 day^{-1})

4.1.7.1 LAD at different stages

Control Vs Rest

A perusal of data presented in table 4.7 and their analysis of variance given in Appendix VIII indicate that application of treatments significantly improved the LAD square decimeter per day (dm^2 day^{-1}) over control at all successive crop growth stages i.e. 30 DAS to harvest during both the years of investigation. On mean result basis, application of treatments improved LAD by 30.01, 40.43, 40.14 and 39.58 per cent at 30, 50, 70 DAS and at harvest over their controls, respectively.

Farm yard manure

Among the FYM levels 10 t ha^{-1} significantly enhanced LAD dm^2 day^{-1} in maize at 30,50,70 DAS and at harvest over 0 and 5 t FYM ha^{-1} during both the years but both the higher levels were found statically at par with each other between 0 to 30 and 30 to 50 DAS during 2002. However, 0 and 5 t FYM ha^{-1} did not have significant variation with each other at all the crop growth stages during both the years of study. Two years mean data show that application of 10 t FYM ha-^{1} improved LAD by 23.21, 17.58, 12.91 and 18.61 per cent between 0-30, 30-50, 50-70 and 70 DAS to harvest over no FYM, respectively.

Fertilizer level

Application of 100% RDF significantly improved LAD dm^2 day^{-1} as compared to 50% RDF at all successive crop growth stages during either year of study. However, 75% RDF also significantly improved the LAD dm^2 day^{-1} between 50-70 and 70 DAS to harvest during both the years. On two years mean result basis, 100% RDF improved LAD by 13.65, 13.94, 15.08 and 14.24 per cent at 30,50,70 DAS and at harvest over 50% RDF, respectively.

Biofertilizer

Seed inoculation either by *Azotobacter* alone or combined inoculation of *Azotobacter* + PSB significantly improved LAD at 50 DAS to harvest but difference between *Azotobacter* alone and no inoculation were non significant at 50 DAS during 2001. On mean data basis, combined inoculation of *Azotobacter* + PSB improved LAD by 7.43, 9.43 and 7.86 per cent at 50,70 DAS and at harvest over control, respectively.

4.1.7.2 Integral mean value of LAD (dm^2 day^{-1})

Control Vs Rest

It is apparent from the data presented in Table 4.8 and their analysis of variance given in Appendix VIII indicate that application of treatments significantly improved the integrated LAD (square decimeter day^{-1}) of whole crop growth period over control during both the years. On mean basis, treatment application enhanced integrated mean value of LAD during the crop growth period by 23.71 per cent over control (19.65 dm^2 day^{-1})

Farm yard manure

Data further show that application of 10 t FYM ha^{-1} significantly enhanced LAD over 5 and 10 t FYM ha^{-1} while, application of 5 t FYM ha^{-1} significantly enhanced LAD at 30, 50, 70 DAS and at harvest during both the years. On mean basis, 10 t FYM ha^{-1} enhanced LAD by 21.82 and 11.13 per cent over no FYM and 5t FYM ha^{-1}, respectively.

Fertilizer level

Application of 100% RDF significantly enhanced the LAD over 50% RDF but statically at par with 75% RDF during both the years. On mean basis, application of 75 and 100% RDF enhanced LAD by 10.83 and 14.45 per cent over 50% RDF, respectively.

Biofertilizer

Seed inoculation with *Azotobacter* alone or combined inoculation of *Azotobacter* + PSB significantly enhanced LAD over no inoculation during both the years. While, difference between combined seed inoculation of *Azotobacter* + PSB and *Azotobacter* alone was also found significant during 2001 but at par during 2002. On mean basis, combined inoculation of *Azotobacter* + PSB enhanced LAD by 7.97 per cent over no inoculation.

4.2 EFFECT OF ORGANIC MANURE, FERTILIZER AND BIOFERTILIZER ON YIELD ATTRIBUTES

4.2.1 Cobs plant^{-1}

Control Vs Rest

An examination of data presented in Table 4.9 and their analysis of variance in Appendix IX show that application of treatment significantly increased the number of cob plant^{-1} over control during both the years. On mean basis, maximum number of cobs plant^{-1} (1.153) was registered under treatment application, which was 16.11 per cent higher over control.

Farm yard manure

Application of 10 t FYM ha^{-1} produced significantly higher number of cobs plant^{-1} over no FYM during both the years. However, 5 t FYM ha^{-1} did not register their superiority over control in this respect and higher level of FYM also proved at par with this level. The mean data of two years indicate that application of 10 t FYM ha^{-1} produced 6.86 and 15.72 per cent more cobs plant^{-1} over 5 t FYM ha^{-1} and no FYM, respectively.

Fertility levels

The lowest number of cobs plant^{-1} were recorded under 50% RDF while number of cobs plant^{-1} increased with increasing level of fertilizers up to 100% RDF. However, both the 100 per cent RDF significantly influenced the number of cobs plant^{-1} over 50% RDF. While, differences between 75 & 100% RDF and 75 & 50% RDF were at par during either year of investigation. On mean result basis, maximum number of cobs plant^{-1} (1.19) were recorded under 100% RDF which was 14.42 per cent higher over 50% RDF (1.04)

Bio-fertilizers

As assessment of data presented in Table 4.9 indicate that seed inoculation of combined strains i.e. *Azotobacter* + PSB produced significantly higher number of cobs plant^{-1} over control. However, while difference between control and *Azotobacter* alone was found non-significant during 2001 while, during 2002 *Azotobacter* proved significantly superior over control. The mean data of two years indicate that maximum number of cobs plants^{-1} (1.15) was recorded with *Azotobacter* + PSB inoculation which was 3.88 and 11.33 per cent higher over *Azotobacter* alone and no inoculation, respectively.

4.2.2 Grains cob^{-1}

Control Vs Rest

In reference to data presented in Table 4.9 and their analysis of variance given in Appendix IX regarding number of grains cob^{-1} significantly influenced by treatment application over control during both the years of experimentation. On mean result basis, treatment application increased number of grains cob^{-1} by 26.25 per cent over control

Farm yard manure

Number of grains cob^{-1} influenced significantly by application of 10 t FYM ha^{-1} over 5 t FYM ha^{-1} and no FYM during both the years. Further data also indicate that differences between 0 and 5 t FYM ha^{-1} were non-significant. Data on mean basis indicate that 10 t FYM ha^{-1} increased number of grains cob^{-1} by 11.73 and 18.66 per cent over 5 t FYM ha^{-1} and no FYM, respectively.

Fertilizer levels

Application of 100% RDF significantly increased number of grains cob^{-1} over 50% RDF but at par with 75% RDF during either year of experimentation. Further, variation between 50% and 75% RDF was also non-significant during both the years. Mean data indicate that application of 100% RDF produced by 10.40 per cent higher number of grains cob^{-1} over 50% RDF (225.53).

Biofertilizers

Seed inoculation with biofertilizers either by *Azotobacter* alone or combined inoculation of *Azotobacter* + PSB significantly increased number of grains cob^{-1} over no inoculation. While, difference between combined inoculation of *Azotobacter* + PSB and *Azotobacter* alone was proved non-significant. On mean basis, maximum number of grains cob^{-1} produced with combined inoculation of *Azotobacter* + PSB by 9.33 per cent over no inoculation (221.76).

4.2.3 Weight of grain cob^{-1}

Control Vs Rest

An appraisal of date presented in Table 4.9 and their analysis of variance given in Appendix IX show that weight of grains cob^{-1} significantly enhanced by treatment application over control either year of experimentation. Two year mean data show that application of treatment improved the weight of grains cob^{-1} by 42.26 per cent over control (36.56).

Farm yard manure

The weight of grains cob^{-1} during both the years of investigation was significantly enhanced due to application of 10 t FYM ha^{-1} and found significantly superior over 0 and 5 t FYM ha^{-1} during the study. While, variation between 0 and 5 t FYM ha^{-1} observed non-significant. Mean data show that among FYM levels 10 t ha^{-1} recorded maximum grains weight cob^{-1} (55.51 g) which was 17.18 higher over control (58.59).

Fertility levels

Increasing dose of fertilizers up to 75% RDF registered significant improvement in grains weight cob^{-1} over 50% RDF but further increase up to 100% RDF did not improve grain weight significantly. Therefore, deference between 75 and 100% RDF was recorded non significant during both the years of investigation. On mean data basis, reveal that 75 and 100% RDF improved grains weight cob^{-1} by 12.16 and 17.18 per cent over 50 %RDF, respectively.

Biofertilizer

Seed inoculation with biofertilizer improved the weight of grains cob^{-1} over no inoculation during both the years. Among the treatments seed inoculation with combined strains i.e. *Azotobacter* + PSB in proved weight of grains cob^{-1} significantly as compared to *Azotobacter* alone during 2002 but both the treatment were at par during 2001 in this respect. On the basis of two years mean data basis, maximum grain weight cob^{-1} (53.48 g) was recorded with combined seed treatment of *Azotobacter* + PSB which was 4.49 and 14.47 per cent higher over *Azotobacter* alone and no inoculation, respectively.

4.2.4 1000- grain weight

Control Vs Rest

In reference to data presented in Table 4.9 and their analysis of variance given in Appendix IX pertaining that 1000- grain weight of maize was significantly influenced by treatment application as compared to control during both the years. On two years mean data basis, application of treatment improved 1000-grain weight by 10.34 per cent over control.

Farm yard manure

Among the FYM levels, application of 10 t ha^{-1} resulted into significant enhancement of 1000-grain weight as compared to no FYM but at par with 5 t FYM ha^{-1} during couple of year of experimentation. Results on two years mean basis, 10 t FYM ha^{-1} enhanced 1000-grain weight by 4.10 and 7.01 per cent over 5 t FYM ha^{-1} and no FYM, respectively.

Fertilizer levels

Increasing dose of fertilizer, indicate an increasing trend in test weight but could not reached up to significance level during both the years. However, maximum value was recorded with 100% RDF. Data on two years mean basis indicate that application of 100% RDF increased 1000-grain weight by 4.34 per cent over 50 per cent RDF.

Biofertilizers

Test weight of maize could not reached up to level of significance by seed inoculation with biofertilizers during both the years of studies. However, maximum 1000-grain weight was recorded with combined inoculation of *Azotobacter* + PSB.

4.3 EFFECT OF ORGANIC MANURE, FERTILIZER AND BIOFERTILIZER ON YIELDS AND HARVEST INDEX

4.3.1 Grain yield

Control Vs Rest

In reference to data presented in Table 4.10 and their analysis of variance given in Appendix X show that application of treatments was proved significantly superior over control during both the years. On mean result basis, application of treatment increased grain yield by 64.06 per cent over control.

Farm yard manure

Among the FYM levels, 10 t FYM ha^{-1} produced significantly higher grain yield over no FYM and 5 t FYM ha^{-1} during both the years of the experimentation. Further, 5t FYM also improved grain yield significantly over control during course of study. On two years mean basis, 10 t FYM ha^{-1} increased the grain yield by 43.89 and 18.56 per cent over no and 5 t FYM ha^{-1}, respectively.

Fertility levels

It is evident from the data presented Table 4.10 indicate that application of 75 and 100% RDF produced significantly higher maize grain yield over 50% RDF but both the aforesaid level were at par with each other during 2001, but in 2002 application of 100% RDF brought about significant variation over 50% RDF while, both the lower doses were at par with each other. On mean results basis, maximum grain yield was obtained at 100% RDF which was about 19.73 and 6.25 per cent more over 50 and 75% RDF, respectively.

Biofertilizers

Seed inoculation with biofertilizers significantly, enhanced the grain yield over no inoculation. Further, data show that seed inoculation either combined strains i.e. *Azotobacter* + PSB or *Azotobacter* alone influenced significantly the grain yield of maize during both the years. Two years mean data reveal that maximum grain yield 29.86 q ha^{-1} registered with combined inoculation which was 3.68 and 12.80 per cent higher over *Azotobacter* alone and no inoculation, respectively. Seed treatment with *Azotobacter* alone produced 8.80 per cent higher grain yield over no inoculation.

4.3.2 Stover yield

Control Vs Rest

It is explicit from data presented in Table 4.10 and their analysis of variance given in Appendix X reveal that application of treatment significantly improved the stover yield of maize over control during both the years of experimentation. Data on mean result basis show that stover yield was improved by 36.99 per cent as compared to control.

Farm yard manure

A perusal of data pertaining to stover yield show that 10 t FYM ha^{-1} significantly increased the stover yield over control and 5 t FYM ha^{-1} during both the years. While, there was non-significant difference between 0 and 5 t FYM ha^{-1} during either year of study. The highest mean stover yield (77.98 q ha^{-1}) was obtained with 10 t FYM ha^{-1} which indicate 19.52 and 20.10 per cent higher over 5 t FYM ha^{-1} and no FYM, respectively.

Fertilizer level

Application of 100% RDF produced maximum stover yield and found significantly superior over 50% RDF but at par with 75% RDF during either year of experimentation. Further, variation between both the lower levels was also non-significant during both the years. Mean data indicated that application of 100% RDF increased the stover yield by 12.46 per cent over 50% RDF (66.21 q ha^{-1}), respectively.

Biofertilizers

Seed inoculation with biofertilizers improved the stover yield significantly over no inoculation during the study. Combined inoculation on *Azotobacter* + PSB proved significantly superior over no inoculation and *Azotobacter* alone during first year experimentation. However, differences between combined inoculation of *Azotobacter* + PSB and *Azotobacter* alone was found non significant during 2002. The mean data of two years reveal that maximum stover yield (72.45 q ha^{-1}) was recorded with combined inoculation of *Azotobacter* + PSB which indicates 13.58 and 4.29 per cent higher over no inoculation and *Azotobacter* alone, respectively. *Azotobacter* alone also produced 9.64 per cent higher stover yield over no inoculation.

4.3.3 Biological yield

Control Vs Rest

A perusal of data presented in Table 4.11 and their analysis of variance given in Appendix X pertaining to biological yield was significantly influenced by treatment application over control during both the years of experimentation. On the two years mean result basis, treatment application increased biological yield by 42.05 per cent over control.

Farm yard manure

Among the levels of FYM, 10 t ha^{-1} significantly enhanced the biological yield over 0 and 5 t FYM ha^{-1} during both the years, while significant difference between 0 and 5 t FYM ha^{-1} was recorded only during 2001. On mean basis, increase in biological yield with 10 t FYM ha^{-1} were by 20.64 and 9.53 per cent respectively over control (89.68 q ha^{-1}) and 5 t FYM ha^{-1} (98.78 q ha^{-1}), respectively.

Fertility Levels

A reference to data pertaining to biological yield reveal that application of 75 and 100% RDF significantly enhanced biological yield over 50% RDF but 75 and 100% RDF levels were at par with each other during both the years. The two years mean data indicate that application of 100% RDF increased the biological yield by 10.09 and 14.23 per cent respectively, over 50 and 75% RDF (92.85 and 102.22 q ha^{-1}, respectively).

Bio-fertilizers

It is evident from data that seed inoculation with single or in combined strains significantly increased biological yield over no inoculation during first years only. While, seed inoculation by *Azotobacter* alone or in combination with PSB was at par during in second year in case of biological yield of maize. Further, combined inoculation with *Azotobacter* + PSB also proved significantly, superior over *Azotobacter* alone during both the years. The highest mean biological yield (103.20 q ha^{-1}) obtained with combined inoculation of *Azotobacter* + PSB which was 4.39 and 14.45 per cent higher as compared to *Azotobacter* alone and no inoculation, respectively.

4.3.4 Harvest Index (H.I.)

Control Vs Rest

Data mentioned in Table 4.11 and their analysis of variance given in Appendix X reveal that application of treatment significantly increased the harvest index over control during both the years, On mean basis, application of treatments increased in harvest index by 9.08 per cent over control (27.09).

Farm yard manure

Data with regard to harvest index of maize indicated that among the FYM levels 10 t ha^{-1} significantly improved the harvest index over control, while there was non-significant differences observed between 5 and 10 t FYM ha^{-1} during both the years. Difference between 0 and 5 t FYM ha^{-1} was noted significant only during 2002. Two years mean results basis, maximum harvest index (30.82) was recorded with 10 t FYM ha^{-1} that result 11.38 per cent higher over control.

Fertility levels

An increasing trend was observed with increasing levels of fertility but different levels of fertility did not influence harvest index significantly at any level during both the years.

Biofertilizer

Seed inoculation with biofertilizers could not enhanced the HI up to the level significance during both the years.

4.4 EFFECT OF ORGANIC MANURE, FERTILIZER AND BIOFERTILIZER ON PROTEIN CONTENT (%) AND PROTEIN YIELD

Control Vs Rest

An appraisal of data regards to protein content and protein yield kg ha^{-1} of maize presented in Table 4.12 and their analysis of variance given in Appendix XI reveal that protein content and yield were positively influenced by treatment application as compared to control during both years. On mean result basis, per cent increase in protein content and protein yield were 6.09 and 66.93 due to treatment application over their controls, respectively.

Farm yard manure

Among the FYM levels 10 t ha^{-1} significantly increased protein content in maize grain over control but difference between 5 and 10 t FYM ha^{-1} were at par with each other. While, protein yield increased significantly with increasing level of FYM during both the years of experimentation. 10 t FYM ha^{-1} was found significantly superior to improve the protein yield over rest of the lower doses during studies. Two years mean results indicate that protein content in grain and yield of protein recorded maximum under 10 t FYM ha^{-1} by 4.73 and 50.69 per cent higher over no FYM, respectively.

Fertilizer levels

All the fertilizers doses from 50 to 100% RDF did not affect significantly protein content of maize during both the years. But protein yield significantly improved by 75 and 100% RDF over 50% RDF, while 75 and 100% RDF were at par with each other during both the years. On mean results basis, 75 and 100% RDF increased protein yield by 14.42 and 22.67 per cent over 50 per cent RDF (284.99 kg ha^{-1}).

Biofertilizers

Data (Table 4.12) evident that seed inoculation with biofertilizers significantly affects the protein content in maize grain and protein yield over no inoculation. While, difference between no inoculation and *Azotobacter* alone was found non significant during 2001. However, combined inoculation of *Azotobacter* + PSB and *Azotobacter* alone were at par during both the years of experimentation. Whereas, combined seed inoculation of *Azotobacter* + PSB and *Azotobacter* alone was found significantly superior over no inoculation during both the years but during 2002 dual inoculation of *Azotobacter* + PSB at par with *Azotobacter* alone. On mean results basis, maximum protein content and protein yield recorded under combined inoculation of *Azotobacter* + PSB which were 1.03 and 16.31 per cent more over their controls, respectively.

4.5 EFFECT OF ORGANIC MANURE, FERTILIZER LEVEL AND BIOFERTILIZER ON NUTRIENT CONTENT NITROGEN CONTENT

4.5.1 Nitrogen content

Control Vs Rest

It is explicit from data in Table 4.13 and their analysis of variance given in Appendix XII indicate that application of treatment significantly increased nitrogen content at all successive crop growth stages and at harvest (in grain and stover) over their controls during both the years. Further, data indicate that nitrogen content was recorded maximum at early crop growth stage i.e. 30 DAS. Thereafter, it decreased simultaneously in later stages of crop growth. Mean data reveal that application of treatments increased nitrogen content by 5.31,7.10,9.56 and 7.98, 7.22 per cent at 30,50, 70 DAS and in grain and stover, over their control, respectively.

Farm yard manure

Among FYM levels, 10 t ha^{-1} increased nitrogen content in maize plant significantly at 50, 70 DAS and at harvest in grain and stover over no FYM but difference between 5 and 10 t FYM ha^{-1} was not significant at all the crop growth stages during both the years. On two years mean basis, nitrogen content increased with 10 t FYM ha^{-1} by 3.46, 7.10, 4.73 and 4.82 per cent at 50,70 DAS, in grain and stover over no FYM, respectively.

Fertilizer level

None of the fertilizer level was found effective in nitrogen content of maize at any stage of crop growth during either year of experimentation.

Biofertilizer

Data depicted in (Table 4.13) reveal that none of the strain can proved their supremely up to 50 DAS stage of crop growth in N content but in later stages i.e. 70 DAS and at harvest, seed inoculation either with *Azotobacter* alone or combination of *Azotobacter* + PSB significantly increased nitrogen content in maize plant over no inoculation during both the year of study. Further, results indicate that difference between control and *Azotobacter* alone was found significant only at 70 DAS during 2001 and in grain during 2002. On the basis of two years mean data, results show that combined inoculation of *Azotobacter* + PSB increased nitrogen content by 2.93 per cent at 70 DAS 3.20 and 6.40 per cent in grain and stover over no inoculation, respectively.

4.5.2 Phosphorus content

Control Vs Rest

An assessment of data presented in Table 4.14 and their analysis of variance given in Appendix XIII reveal that application of treatments significantly increased phosphorus content at all successive crop growth stages i.e. 30 DAS to harvest (grain and stover) over control during both the years. Further, data indicate that maximum accumulation of phosphorus content was recorded at early crop growth stage i.e. 30 DAS thereafter, it was decreased simultaneously. Two years mean data indicate that application of treatments increased accumulation of P-content by 5.78, 6.25, 5.15 and 7.57 13.51 per cent at 30,50, 70 DAS and in grain and stover over their controls, respectively.

Farm yard manure

Application of FYM significantly improved the phosphorus content up to harvest over control in maize except 30 DAS stage. Application of 10 t FYM ha^{-1} significantly improved the accumulation of phosphorus content in maize over no FYM but difference between 5 and 10 t FYM ha^{-1} was non-significant during both the years. Two years mean result basis, application of 10 t FYM ha^{-1} increased phosphorus content by 4.63, 5.03 and 5.31, 7.41 per cent at 50,70 DAS and in grain and stover over their controls, respectively.

Fertilizer level

Application of fertilizer from 50 to 100% RDF did not increase significantly phosphorus content in maize plant from 30 DAS to harvest (grain and stover) during both the years except 50 and 70 DAS during 2001. However, at 50 and 70 DAS application of 100% RDF was significantly superior over 50% RDF in this respect during 2001.

Biofertilizer

Combined seed inoculation of *Azotobacter* + PSB significantly increased phosphorus content in maize plant from 50 DAS to harvest (grain and stover) over control. While, *Azotobacter* alone significantly increased phosphorus content in grain during 2001 only. Mean results of two consecutive years indicate that combined inoculation of *Azotobacter* + PSB increased phosphorus content by 1.70, 5.12, 4.00, 7.07 and 5.55 per cent at 30,50, 70 DAS and in grain and stover over control, respectively.

4.5.3 Potassium content

Control Vs Rest

In reference to data on potassium content of maize presented in table 4.15 and their analysis of variance given in Appendix XIV reveal that application of treatments have increasing trend in potassium content of maize plant but did not reach to the level of significance over control at different successive crop growth stages but in grain and stover differences were recorded significant during both the years. Further, data show that potassium content was higher at initial stage i.e. 30 DAS and thereafter content was simultaneously decreased. Mean results of two consecutive years indicate that percent increase in grain and stover was by 5.72 and 4.62 over control, respectively.

Farm yard manure

Application of FYM did not improve potassium content significantly in maize plant at all crop growth stages during both the years.

Fertilizer level

Different level of fertilizers failed to show significant improvement in potassium content and found at par at all crop growth stages as well as in grain and stover at harvest during both the years.

Biofertilizers

Similar trend was noted in case of biofertilizer. Seed inoculation with biofertilizer did not enhance the potassium content significantly at all crop growth stages including grain and stover during both the years.

4.6 EFFECT OF ORGANIC MANURE, FERTILIZER LEVEL AND BIOFERTILZER ON NUTRIENT UPTAKE

4.6.1 Nitrogen uptake

Control Vs Rest

It is evident from data presented in Table 4.16 and 4.17 their analysis of variance given in Appendix XV and XVI reveal that there is a continuous uptake of N throughout the growing season, although the quantity on nitrogen latter decreases as the crop approaches maturity. However, out of total N uptake throughout growing season crop was taken 8.70 , 25.90, 51.2 and 14.20 per cent nitrogen at successive crop growth stages i. e. 30, 50, 70 DAS and at harvest, respectively, under control plot. While under rest of the treatments out of total N uptake, uptake of N by 9.40, 28.70, 50.70 and 11.20 per cent at 30, 50, 70 DAS and at harvest, respectively. Further, under rest treatment total N uptake at different successive stages were 10.40, 31.61, 55.87 and 12.38 kg ha^{-1} (Out of total N uptake 110.26 kg ha^{-1}) between 0-30, 30-50, 50-70 DAS and at harvest, respectively results also indicate that application of treatment significantly increased nitrogen uptake over control at all successive crop growth stages and at harvest in grain and stover during both the years. On mean basis, application of treatments increased N uptake by 69.66, 71.68, 61.36 and 55.95 per cent at 30, 50 , 70 DAS and at harvest over their controls, respectively. Nitrogen uptake was increased in grain and stover by 69.54 and 44.39 per cent over their controls, respectively.

Farm yard manure

Among the FYM levels, application of 10 t ha^{-1} significantly increased the uptake of nitrogen at different successive crop growth stages i.e. 30 DAS to harvest in grain and stover over 0 and 5 t FYM ha^{-1} during both the years. On mean result basis, application of 10 t FYM ha^{-1} enhanced the uptake of nitrogen by 31.94, 27.77, 30.03 and 36.32 per cent at 30,50,70 DAS and at harvest over no FYM, respectively. Similarly 10 t FYM ha^{-1} increased nitrogen uptake though grain and stover by 47.30 and 28.20 per cent as compared to no FYM, respectively.

Fertilizer levels

Application of 75 and 100% RDF significantly enhanced uptake of nitrogen in maize plant over 50% RDF at all successive crop growth stages i.e. 30 DAS to harvest during both the years. While, 75 and 100% RDF were at par at all crop growth stages during both the years. Similar trends were observed in nitrogen uptake by grain and stover except in grain during 2001. On two years mean basis, 75 and 100% RDF increased nitrogen uptake by 10.03, 16.04, 13.16, 12.94 and 14.53, 21.48, 18.29,20.49 per cent at 30,50,70 DAS and at harvest over 50% RDF, respectively.

Biofertilizer

Nitrogen uptake significantly enhanced in maize crop by seed inoculation with *Azotobacter* alone or combined inoculation of *Azotobacter* + PSB during both the years. While, combined inoculation of *Azotobacter*+ PSB was at par with *Azotobacter* alone at all successive crop growth stages except 50 DAS to at harvest during 2001 and 2002, respectively. Similar trend was observed in grain and stover in regards to nitrogen uptake by crop. On two years mean result basis, combined inoculation of *Azotobacter* + PSB and *Azotobacter* alone enhanced nitrogen uptake at 30, 50, 70 DAS and at harvest by 14.80,17.42,14.65,15.82 and 10.77, 16.09, 9.99, 13.75 per cent over their controls respectively. Similarly seed inoculation with combined strains of *Azotobacter* + PSB enhanced the uptake of nitrogen in grain and stover by 17.21 and 19.95 per cent over control, respectively.

4.6.2 Phosphorus uptake

Control Vs Rest

A reference to date presented in Table 4.18 and 4.19 and their analysis of variance given in Appendix XVII and XVIII reveal that phosphorus uptake by maize was continuous throughout the growing season, although the quantity of phosphorus uptake latter decreases as the crop approaches maturity. The largest phosphorus requirement in maize occurs after flowering and during repining period. However, during the experimentation period it was observed that maize crop continuously uptake the phosphorus throughout the growing season by 5.5, 17.8, 50.0 and 26.7 per cent at 30, 50, 70 DAS and at harvest, respectively. However, the P uptake at 30, 50, 70 DAS and at harvest was 1.3, 4.2, 11.8 and 6.3 kg ha^{-1} (Out of total P uptake 23.6 kg ha^{-1}). Results also indicate that application of treatment significantly enhanced the phosphorus uptake by maize crop over control at all successive crop growth stages during both the years of experimentation. Two years mean data show that application of treatments increased the phosphorus uptake by 69.92, 71.0, 55.03 and 65.68 per cent at 30,50,70 DAS and at harvest, respectively over their controls. Similarly, treatment application enhanced the P uptake in grain and stover by 70.88 and 57.44 per cent over their controls, respectively.

Farm yard manure

Data further show that uptake of phosphorus significantly enhanced by 10 t FYM ha^{-1} over 0 and 5 t FYM ha^{-1} at all successive growth stages during both the years except in grain during either year of studies. However, 5 t FYM ha^{-1} failed to show their superiority over no FYM at all the stages of crop growth except 30 DAS during 2001 and at harvest during 2002. Similar trend regarding P uptake was also recorded in grain. While, P content in stover significantly improved with 10 t FYM ha^{-1} over control and 5 t FYM ha^{-1}. Mean results of two conjunctive years indicate that application of 10 t FYM ha^{-1} enhanced phosphorus uptake by 31.35, 28.78, 17.68 and 39.32 per cent at 30, 50, 70 DAS at harvest over their controls, respectively. Similarly, P uptake in grain and stover were increased by 30.69 and 24.60 per cent over control, respectively.

Fertilizer level

Increasing dose of fertilizer 75 to 100 per cent RDF significantly enhanced phosphorus uptake over 50% RDF but difference between 75 and 100% RDF was not significant at different crop growth stages from 30 DAS to harvest during both the years.

While, 75% RDF was at par with 50% RDF at 70 DAS and at harvest during 2002. However, P uptake in grain did not enhanced significantly with increasing levels of fertilizer from 50 to 100% RDF, whereas 100% RDF significantly enhanced the P uptake in stover over 50% RDF. Two years mean data indicte that application of 75 and 100% RDF increased total P-uptake by 14.96, 16.78, 12.62, 13.87 and 20.99, 21.96, 17.68, 20.49 per cent at 30,50,70 DAS and at harvest over their respective 50% RDF, respectively.

Biofertilizer

Seed inoculation either by *Azotobacter* alone or co-inoculation of *Azotobacter* + PSB significantly enhanced P uptake in maize crop during both the years. However, combined inoculation of *Azotobacter* + PSB was found significantly superior over *Azotobacter* alone during both the years of experimentation except 30 DAS during 2002 and in stover during 2001. Data on two years mean basis, co-inoculation of *Azotobacter* + PSB enhanced P uptake in maize crop by 14.92, 20.73, 15.72 and 21.54 per cent at 30,50,70 DAS and harvest over their controls, respectively.

4.6.3 Potassium uptake

Control Vs Rest

As perusal of data presented in Table 4.20 and 4.21 and their analysis of variance given in Appendix XIX and XX indicate that 99 per cent of total K requirement is taken up by maize before grain filling stage, however most of the K uptake is completed before grain filling begin to develop. Further, data indicate that application of treatment enhanced the K uptake in maize over control at all successive crop growth stages during both the years. On mean result basis, K uptake enhanced due to treatment application by 57.27, 63.28, 50.37 and 44.50 per cent at 30, 50, 70 DAS and at harvest over their controls, respectively. Similar trends were also observed in grain and stover regarding K uptake with treatment application over control. Increases in K uptake in grain and stover were recorded in tune of 67.22 and 4.39 per cent over their controls, respectively.

Farm yard manure

Among the FYM levels, 10 t ha^{-1} enhanced the K uptake significantly over 0 and 5 t FYM ha^{-1} in maize at all successive crop growth stages i.e. 30 DAS to harvest during both the years, but at 30 DAS higher dose of FYM was at par with 5 t FYM ha^{-1} during 2001. Similarly, 10 t FYM ha^{-1} significantly enhanced K uptake in grain and stover as compared to 0 and 5 t FYM ha^{-1} during both the years of experimentation. Mean results of two consecutive years reveal that application of 10 t FYM ha^{-1} enhanced K uptake by 30.62, 24.61, 25.54 and

26.01 per cent at 30, 50, 70 DAS and at harvest over their controls, respectively Similar trends in respect to K uptake were also observed in grain and stover of maize increases were 45.86 and 23.58 per cent over their controls, respectively.

Fertilizer level

Application of 100% RDF significantly enhanced K uptake over 50% RDF but it was at par with 75% RDF at all successive stage of crop growth i.e. 30 DAS to harvest during both the years. However, 75% RDF significantly increased total K uptake at 30, 50, 70 DAS during 2001 and 30 DAS and at harvest during 2002, respectively over 50 % RDF. Similarly, 100% RDF significantly enhanced K uptake in grain and stover over 50% RDF during both the years. On mean results basis, 100% RDF increased K uptake in maize by 19.72, 19.75, 16.15 and 18.09 per cent at 30,50,70 DAS and at harvest over their respective 50 % RDF, respectively.

Biofertilizers

Combined inoculation of *Azotobacter* + PSB significantly promoted K uptake in maize over no inoculation but at par with *Azotobacter* alone at all successive crop growth stages i.e. 30 DAS to harvest during both the years. Further, combined inoculation with *Azotobacter* + PSB was also found significantly superior over *Azotobacter* alone at 50 DAS during 2001. Similarly, combined inoculation of *Azotobacter* + PSB enhanced significantly K uptake in grain and stover of maize over no inoculation but at par with *Azotobacter* alone during both the years. On two years mean results basis, combined inoculation of *Azotobacter* + PSB increased P uptake by 13.12, 6.19, 11.73 and 15.49 per cent at 30, 50, 70 DAS and at harvest over their controls, respectively.

4.7 EFFECT OF ORGANIC MANURE, FERTILIZER LEVEL AND BIOFERTILIZER ON AVAILABLE NUTRIENT AND ORGANIC CARBON (%) IN SOIL

4.7.1 Available nitrogen

Control Vs Rest

Available N status of soil at harvest of maize presented in Table 4.22 and their analysis of variance given in Appendix XXI indicate that nutrient applied in soil to maize significantly effect on available N status of soil as compared to control after maize crop harvest. On mean basis N status improved 14.08 kg N ha^{-1} as compared to control (23.10 kg N ha^{-1})

Farm yard manure

Application of 10 t FYM ha^{-1} significantly improved N status in soil as compared to no FYM but difference between 5 and 10 t FYM ha^{-1} was at par during both the years. However, maximum mean value for available N (260.53 kg ha^{-1}) was observed with 10 t FYM ha^{-1} that improved 15.91 kg N ha^{-1} over no FYM (244.62 kg N ha^{-1}).

Fertilizers levels

Available N status in soil analysed maximum with 100% RDF but all fertility levels were found at par with each other during both the years of experimentation after maize harvest.

Biofertilizers

Seed inoculation with biofertilizers could not improved significantly N status in soil at harvest stage of maize during either year of experimentation.

4.7.2 Available phosphorus

Control Vs Rest

Data pertaining to available phosphorus status in soil at harvest of maize presented in Table 4.22 and their analysis of variance given in Appendix XXI exhibit that application of treatment were found significantly effective to improve the P status in soil at harvest stage of maize as compared to control during either yearof study. On mean results basis P status in soil enhanced 4.31 kg P ha^{-1} at maize harvest as compared to control (20.99 kg P ha^{-1})

Farm yard manure

Among the levels of FYM application of 10 t ha^{-1} significantly improved the P status in soil at maize harvest over control during both the years. Further, application of 10 t FYM ha^{-1} brought about significant variation over 5t FYM ha^{-1} during first year of experimentation but in second year both these doses were at par with each other in case of available P in soil at harvest stage of maize. On two years mean basis, maximum mean value for available P (26.61 kg ha^{-1}) was observed with 10 t FYM ha^{-1} and this treatment improved P status 4.31 kg P ha^{-1} as compared to no FYM.

Fertilizer levels

Among fertilizer levels 100% RDF was significantly improved the P status in soil at harvest. While, both the lower levels of fertilizer could not improved the P status in soil up to significant level during both the years. Both higher levels i.e. 75 and 100% RDF achieved at par in case of available P in soil only during 2002. Two years mean result basis maximum available P recorded with 100% RDF which improved P status 2.15 kg P ha $^{-1}$ over 50 per cent RDF.

Bio-fertilizers

Seed inoculation with *Azotobacter* + PSB significantly improved the P status in soil at harvest over control and *Azotobacter* alone during both the years. However, on mean basis maximum available P was recorded under seed inoculation of *Azotobacter* + PSB (26.21 kg ha^{-1}) which improved 2.12 kg P ha $^{-1}$ in soil over no inoculation at maize harvest.

4.7.3 Available potassium

Control Vs Rest

Available K status of soil at harvest stage of maize presented in Table 4.22 and their analysis of variance given in Appendix XXI reveal that application of organic manure (FYM), fertilizer levels and biofertilizers in maize could not improved significantly the available K status in soil at maize harvest during both the years of investigation. On mean basis, maximum value of available K in soil at maize harvest (357.72 kg ha^{-1}) under 10 t FYM ha^{-1}.

4.7.4 Organic carbon (%) in soil

Control Vs Rest

Data presented in Table 4.22 and their analysis of variance given in Appendix XXI show that application of treatment improved the organic carbon percent in soil at harvest during both the years. On mean result basis, maximum mean value of organic carbon (0.416%) was observed with treatment application as compared to control (0.372 %.

Farm yard manure

Among the FYM levels, 10 t ha^{-1} significantly improved organic carbon status in soil at maize harvest as compared to no FYM during both the years. Two years mean results basis, Maximum mean value of organic carbon (0.446%) was recorded with 10 t FYM ha^{-1} over control (0.387%).

Fertilizer levels

Application of fertilizer levels from 50 to 100% RDF could not significantly improved the organic carbon status in soil during either year of experimentation.

Bio fertilizers

Seed inoculation with biofertilizers did not improve the organic carbon status up to a significant level in soil at harvest during both the years. On mean basis, combined inoculation of *Azotobacter* + PSB recorded maximum value of organic carbon (0.416 %) in soil at maize harvest over no inoculation (0.406%).

4.8 BALANCE SHEET

4.8.1 Nitrogen status

Control Vs Rest

An examination of data presented in Table 4.23 after harvest of maize crop show that, application of treatment reduced the negative balance of soil nitrogen as compared to control plot. It was observed that reduction of soil nitrogen was 18.66 kg ha^{-1} over initial status under control plot, while under treatment application reduction was 4.53 kg ha^{-1}. However, due application of treatment improved the nitrogen status (14.43 kg ha^{-1}) over control.

Farm yard manure

On mean data basis, among the FYM levels, 10 t FYM ha^{-1} improved nitrogen status positively (2.78 kg ha^{-1}) as compared to no FYM (9.72 kg ha^{-1} N loss). Further, it is clearly signifies significant role of FYM in maintaining soil fertility. While, 5 t FYM ha^{-1} also improve the nitrogen status in soil and reduced negative balance of soil available nitrogen but did not reach up to positive value of nitrogen status (6.75 kg ha^{-1} N loss).

Fertilizer level

Two years mean data show that application of 100% RDF improved the soil available nitrogen status positively over rest of the lower doses. However, positive value of soil available nitrogen status was recorded 0.36 kg ha^{-1} under 100 % RDF over 50% RDF (9.75 kg ha^{-1} N loss). Further, data indicate that application of 100% RDF improved the nitrogen status 8.98 kg ha^{-1} and maintained the soil fertility over 50% RDF.

Biofertilizer

On mean value basis, after harvest of maize crop show that seed inoculation by *Azotobacter* alone or with combined inoculation of *Azotobacter* + PSB reduced negative balance of nitrogen in the soil but did not reach up to positive value. However, due to combined seed inoculation with *Azotobacter* + PSB reduction of soil nitrogen measured by 4.76 kg ha^{-1} as compared to no inoculation (7.72 kg ha^{-1} N loss).

4.8.2 Phosphorus status

Control Vs Rest

Phosphorus balance sheet over the years for maize crop (Table 4.24) indicate that application of treatment improved available phosphorus status of the soil over its initial value after harvest of maize crop. Application of treatment increased soil phosphorus, status by 4.31 kg ha^{-1} over no FYM (0.66 kg ha^{-1} loss).

Farm yard manure

Application of FYM also builds up soil available phosphorus over no FYM. Further, data indicate that application of 10 t FYM ha^{-1} improved phosphorus status positively (2.74 kg more) over no FYM application (2.22 kg ha^{-1}).

Fertilizer level

Application of fertilizer doses positively improved available phosphorus status of the soil. However, application of 100% RDF improved phosphorus status 2.15 kg ha^{-1} over 50% RDF (2.60 kg ha^{-1}).

Biofertilizers

Seed inoculation with biofertilizers either *Azotobacter* alone or combination of *Azotobacter* + PSB tended to build up available phosphorus in the soil by 0.23 and 2.13 kg ha^{-1} over no inoculation, respectively after harvest maize crop.

4.8.3 Potassium status

Control Vs Rest

Balance sheet for potassium indicate that application of treatment build up available potassium in the soil after harvest of maize crop (Table 4.25) application of treatment reduce the negative balance of soil potassium status and it improved 9.91 kg ha^{-1} over control (0.81 kg ha^{-1} loss).

Farm yard manure

Increasing doses of FYM improved the potassium status in soil after maize harvest. Application of 10 t FYM ha^{-1} to maize crop builds up soil potassium by 8.56 kg ha^{-1} over no FYM (5.02 kg ha^{-1}).

Biofertilizer

Seed inoculation with Azotobacter alone not have more impact on potassium status in soil while, combined seed inoculation with *Azotobacter* + PSB improve the potassium status by 1.69 kg ha^{-1} as compared to no inoculation (7.26 kg ha^{-1}).

4.9 ECONOMICS OF MAIZE AS INFLUENCED BY ORGANIC MANURE, FERTILIZER LEVEL AND BIOFERTILIZER

Control Vs Rest

Data on monitory advantage based on two years of experimentation presented in Table 4.26 and their Appendix XXII indicated that application of treatment obtained significantly higher gross, net monitory returns and benefit: cost ratio as compared to during course of study. Two years mean results show that applicaton of treatments obtained net return(Rs 23575 ha^{-1}), gross return (Rs 13440 ha^{-1}) and benefit cost ratio of (1.74) as compared to control (Rs. 159045 ha^{-1} , Rs. 9771 ha^{-1} and 1.59).

Farm yard manure

Increasing level of FYM improved gross and net monetary returns significantly over control but in case of B: C ratio these were found at par with each other during either year of experimentation. However, application of 10 t FYM ha^{-1} obtained significantly higher net and gross monetary returns over 5 t FYM and no FYM during both the years. Two years mean result show that 10 t FYM ha^{-1} obtained maximum gross return (Rs 27274 ha^{-1}), net return (Rs 17431 ha^{-1}) and benefit: cost ratio (Rs 1.74) over control.

Fertilizer levels

Application of 100% RDF recorded higher gross return and net monitory returns with B:C ratio over 50% RDF but at par with 75% RDF during both the years of study except in case of B: C ratio was found at par during 2002. On two years mean basis result indicate that application of 100% RDF obtained maximum gross return (Rs 25239 ha^{-1}), net return(Rs 16244 ha^{-1}) and B:C ratio (1.81) over 50 % RDF (Rs. 21527 ha^{-1}, Rs,. 13344 ha^{-1} and 1.60, respectively).

Bio-fertilizers

Seed inoculation either *Azotobacter* alone or in combination of *Azotobacter* + PSB obtained significantly higher values of gross returns, net returns and benefit: cost ratio over no inoculation during course of study. However, seed inoculation with *Azotobacter* + PSB was found significantly superior over *Azotobacter* alone during 2001 but at par during 2002. On mean basis, maximum grsoo return (Rs. 24030 ha^{-1}), net return (Rs. 15660 ha^{-1}) and benefit: cost ratio of 1.87 were recorded under combined inoculation of *Azotobacter* + PSB as compared to control (Rs. 21238 ha^{-1}, Rs. 12915 ha^{-1} and 1.55, respectively).

Economics based on treatment combinations

Based on economic viable treatment (Table 4.27 and appendix XXIII and XXIV) it is observed that treatment combination of 10 t FYM ha^{-1} + 100% RDF along with combined seed inoculation of *Azotobacter* + PSB was found most remunerative and gave maximum gross (Rs. 29875 ha^{-1}) and net (Rs. 19640 ha^{-1}) returns followed by 10 t FYM + 75% RDF along with seed inoculation of *Azotobacter* + PSB with gross and net returns of Rs. 29186 and Rs. 19315 ha^{-1}, respectively.

Highest B:C ratio of 1.96 was recorded from the treatment combination of 10 t FYM + 75% RDF + seed inoculation of *Azotobacter* + PSB followed by 10 t FYM + 100% RDF + seed inoculation of *Azotobacter* + PSB with B:C ratio 1.92.

5. DISCUSSION

The experimental findings presented in the preceding chapter provide a detail account of the effect of organic manure, fertilizer levels and biofertilizers on the growth, yield and yield attributes, nutrient content and their uptake by crop. Some of the other parameters showed consistent trend in the data, though non-significant. It is, therefore, imperative to analyze such variations and thereby intercept cause and effect relationship for ascertaining the effect of treatments. The primary object which motivated this investigation was whether the yield of maize could be increased by integrated nutrient management and sustain the soil fertility by economically viable treatment combination, which doing so, the pertinent findings of other research workers have been cited in order to provide further support to the results obtained in the present investigation. For convenience and clarity, the entire results have been categorized under suitable headings and discussed accordingly.

5.1 CROP SEASON

The results indicated that between the years of investigation, the productivity of maize crop in terms of grain, stover and biological yields were higher by 8.56, 18.08 and 15.25 per cent, respectively during the year 2001 over second year of experimentation (2002).

In general, as the crop was grown under identical management conditions and input level, the observed variation in productivity of maize crop between the years seems to be due to variation in weather conditions which prevailed during various stages of crop growth. The profound influence of environmental factor on crop productivity is well documented. Mavi (1986) stated that plant can be realize its genetic potential or complete its genetically programmed phasic development under certain range of environmental factors. While, Mistry and Patel (1977) opined that weather is principal input parameter, which brings year to year variation in crop productivity despite consistency of other input parameters and practices of crop husbandry.

The mean weekly weather parameters recorded during maize crop growth period showed marked variation in amount and distribution of rainfall and sunshine hours between the years (Appendix I and II). While, differences in other parameters were marginal. During the first year of experimentation (year 2001), the total rainfall received during rainy season was 668.4 mm, which was well distributed across various stages of plant growth except grain filling stage and occurred long dry spell. Therefore, one life saving irrigation was given at this stage for successful crop production. However, during the year 2002 (second year), the total rainfall received during maize growing season was drastically lower (224.9 mm) and ill distributed too. Despite of life saving irrigation, one irrigation was given at grain filling stage of maize crop. While, comparatively higher quantum of rainfall with proper distribution in the year 2001 seems to have provided congenial conditions (both above and below the ground) for proper growth and development of maize plants. This well evince from increased growth parameters (final plant height, LAI, CGR, NAR and LAD) as well as overall growth of the crop in terms of biomass accumulation plant^{-1} at successive stages of crop growth and improvement in final biomass plant^{-1} at harvest was 4.32 per cent as compared to 195.87 g plant^{-1} recorded during year 2002.

It is an established fact that adequate supply of metabolites and nutrients is prerequisites for proper growth and development of each yield components, the adequate supply of these inputs during the year 2001 ultimately reflected in improvement of each yield component. Since grain yield is artifact of several yield components, the marked increases in yield components during year 2001 manifested in realization of higher grain yield by 4.32 per cent over that recorded during year 2002. The increased stover yield during second year compared to first year of study seems to be on account of better growth of the crop as evince from increase in morphological parameters along with dry matter accumulation by the plants. Since biological yield is sum of grain and stover yield, the increase in both these led to realize higher biological yield during year 2001 compared to year 2002.

5.2 EFFECT OF TREATMENT APPLICATION

All applied treatments consisting FYM (0, 5 and 10 t ha^{-1}), N, P, K fertilizer (50, 75 and 100% RDF) and biofertilizer (no inoculation, *Azotobacter* and *Azotobacter* + PSB) fertilization resulted in a significant improvement in most of the growth parameters, yield attributes and yield of maize over that absolute control, respectively. Besides, marked increase was also recorded in content and uptake of nutrients (N, P and K) due to treatment application (Table 4.2 to 4.21). However, K content in plant from 30 DAS to 70 DAS under treatment application was at par with main plot control.

It is well known fact that N, P and K performs a vital role in the life cycle of the plant specifically in nucleic acid of genes and chromosomes, carrying the genetic material from cell to cell and seed to seed (Khaswaneh *et al.*, 1986). Application of treatments as a combined use of organic manure, chemical fertilizer, biofertilizer has been found to be promising not only maintaining higher productivity but also in providing stable crop yield. Application of treatment favourably and significantly enhanced grain, stover, biological yields and harvest index as compared to main plot control. The results are in conformity with the findings by

Nambiar and Abrol (1989); Tomer e*t al*. (1992) and Sawarkar (2003). Out of three major nutrients, there is a continuous uptake of P and N throughout the growing season, although the quantity of latter decreases as the crop approaches the maturity, there is a practically no uptake of K after 90 DAS. The largest P requirement in maize occurs after flowering and during the ripening stage (Jain, 1981). He also reported that there was continuous uptake of P during the growing season, though up to the commencement of flowering, only 25 per cent of the quantity of P requirement had been absorbed. Regarding K, 60 per cent of total K requirement is taken up before flowering and most of the uptake is completed before grain filling begins to develop.

5.3 EFFECT OF FYM

5.3.1 Growth parameters

The results indicate that application of organic manuring through 10 t FYM ha^{-1} significantly enhanced morphological parameters of growth (LAI from 30 DAS to harvest and final plant height) consequently biomass $plant^{-1}$ at 30 DAS to onwards). However, at harvest the crop under the influence of FYM accumulated higher biomass by 18.36 per cent (Table 4.2, 4.4 and fig. 4.1). Significant improvement in plant height, LAI, CGR, NAR and LAD might have resulted into better interception, absorption and utilization of radiant energy leading to higher photosynthetic rate and finally more accumulation of dry matter by plants (Table 4.2 to 4.8).

Organic matter also functioned as source of energy for soil mycoflora, which bring about transformation of inorganic nutrients held in the soil or applied in the form of fertilizers, in readily form that is utilized by growing plants. The beneficial effect of FYM addition is also related to improvement in soil physical properties (Laddha, 1993).

It is well documented fact that incorporation of organic manures in the soils not only acts as store house of major and micro nutrients but also favorably effect on physical, chemical and biological properties of the soils (Biswas *et al*., 1967). Thus potential role of organic fertilization on various aspects of crop growth can be ascribed due to its direct effect on availability of vital nutrients along with physico-chemical and biological properties of soils and indirectly via release of growth hormones, vitamins and augmenting microbial population etc. during its process of decomposition (Gaur and Mathur, 1966; Gaur *et al*., 1973; Mathur and Gaur, 1977).

Thus under the present study marked improvement in morphological parameters of crop growth (plant height, LAI, CGR, NAR and LAD) under organic fertilization seems to be due to greater metabolic activities mediated by congenial nutritional environment as well as inputs vitally required for crop growth. Since LAI, CGR, NAR and LAD are considered to be main determinates of dry matter accumulation by the plants, thus their improvement with addition of FYM manifested in higher production of biomass at 30 DAS to harvest of the crop (Table 4.3). The correlation studies also indicated positive interrelationship between plant height, LAI, CGR, NAR, LAD and dry matter accumulation (Table 5.1). While, regression analysis revealed that unit increases in LAI (at harvest), CGR (70 DAS to harvest), NAR (70 DAS to harvest) and itegeral mean value LAD (dm^2 day^{-1}) improved final dry weight of plants by 118.278, 7.205, 28.691 and 40.958 g $plant^{-1}$, respectively (Table 5.1). Integral mean value of $\overline{LAD}$ highly correlated with yield of field crops and found that the NARs during periods of rapid growth were quite similar in field crops but $\overline{LAD}$s for these crops differed significantly (Watson, 1947).

Hence, improvement in growth efficiency parameters of maize crop under the influence of organic fertilization could be solely ascribed due to its pivotal role in enhancing biomass accumulation at later stages of crop growth. Khandey and Thakur (1990); Shekhon and Aggarawal (1994) also reported an increase in growth parameters of maize due to application of FYM. Gaur and Rao (1984) observed the increasing the leaf area index of maize with FYM application. Gangwar and Singh (1992) and Rameshwar and Singh (1988) also reported that application FYM increased dry matter production of maize.

In the preceding section, correlation studies indicated significant interrelationship between yield components and yield while regression analysis revealed strong dependence of grain yield on various yield components (Table 5.1). These results clearly suggest that grain yield affected from several yield components, which are depended on source (photosynthates/metabolites/nutrients) and sink (yield components particularly cobs $plant^{-1}$ grain weight cob^{-1}, grains cob^{-1}) and improvement in all these aspects under the influence of organic fertilization resulted in realization of higher productivity in terms of grain yield. Under the present study the established interrelationship between grain yield and different biometrics characters also validated positive significant "r" between component *viz*., cobs $plant^{-1}$ (r=0.973*), grains cob^{-1} (r=0.937*), grain weight cob^{-1} (r=907*) and 1000-grain weight (r=0.862*). While, regression analysis revealed that unit increases in cobs $plant^{-1}$, grains cob^{-1}, grain weight cob^{-1} and 1000-grain weights are responsible to increased grain yield by 44.999, 0.714, 0.501 and 0.531 q ha^{-1}, respectively (Table 5.1). Increase in grain yield of maize due to FYM application was also reported by Negi *et al*. (1992); Khandey *et al*. (1993); Suri and Puri (1997); Rameshwar and Singh (1997); Sharma and Gupta (1998) and Pandey (1998).

5.3.2 Yield attributes and yield

Application of 10 t FYM ha^{-1}significantly improved various yield attributes namely cobs $plant^{-1}$, number of grains cob^{-1}, grain weight cob^{-1} and 1000-grain weight with concomitant increase in productivity of maize crop (Table 4.9). The magnitude of increase in grain, stover and biological yield were to extent of 43.89, 12.01 and 20.64 per cent with incorporation of 10 t FYM ha^{-1} over no organic manure (Table 4.10 and 4.11).

The marked increase in various yield components with addition of FYM seems to be not only due to adequate supply of assimilates/nutrients but also to its pivotal role in enhancing physico-chemical and biological properties of the soil, which as greater impact on growth of roots. In the recent years, with increasing evidences on potential role of growth hormones in yield formation it has been advocated that balanced hormonal pattern in plant system exert profound influence on proper development of growth and reproductive structures ultimately productivity of the crop. Thus enhanced root activities under organic fertilization might have increased cytokinin synthesis resulting in increased vegetative and reproductive growth of the plants. Further, it has been reported that cytokinin mostly synthesized in root tips plays active role especially in cell division and their growth.

The studies on yield formation in maize crop have clearly established that only a small amount (10%) of carbohydrate accumulated in vegetative organs contributes towards yield formation but dry matter accumulation at later stages i.e. after initiation of tassels plays vital role. Thus, higher photosynthetic efficiency of plants estimated in terms of biomass accumulation and CGR under organic fertilization seems to be one of the potential factors for improving various yield components.

In the preceding section, it was emphasized that the FYM brought about significant improvement in overall growth of the crop expressed in terms of LAI, dry matter production, crop growth rate, net assimilation rate, leaf area index by virtue of increased photosynthesis efficiency. Thus greater availability of metabolites (photosynthates) and nutrient to developing reproductive structures seems to have resulted in increase in their number and growth, increased in yield attributes with FYM.

The increase stover production with addition of FYM seems to be on account of increased photosynthetic efficiency and greater development of vegetative structures. While higher production of total biomass under FYM application seems to be on account of its profound influence on both vegetative and reproductive events of crop growth. The correlation studies also subsisted significant positive relationship between stover yield and plant height (r=0.917) as well as DMA at harvest (r=0.947), LAI at harvest (r=0.955), CGR between 70 DAS to harvest (r=0.830), NAR between 70 DAS to harvest (r=0.929) and integral LAD (r=0.956).

The increase in harvest index may be attributed by increased translocation of photosynthates from source to sink. The results corroborate the findings of Sriniwasan (1992), Rameshwar and Singh (1997) and Sakal *et al*. (1999). While, regression analysis also validated that unit increase in grain and stover yields increased biological yield by 2.50 and 1.618 q ha^{-1}, respectively. Results are in close conformity with the findings of Sharma and Sinha (1985); Biswas and Benbi (1997) who also reported increase in stover and biological yields due to FYM application.

5.3.3 Seed quality

The increase in protein content seems to have resulted in higher accumulation of nitrogen content in grain. Thus, protein content and protein yield significantly enhanced due to 10 t FYM application over no FYM (Table 4.12). However, improvement in nutritional status of plant might have resulted in greater synthesis of amino acid and protein and other growth promoting substances, which seems to have enhanced protein content and protein yield in maize. Results are in close conformity with the finding of Mishra *et al*. (2002), who also reported increase protein content and yield in maize due to FYM application.

5.3.4 Content and uptake of nutrients

The results indicate that application of 10 t FYM ha^{-1} significantly elevated nutrient content between 30 DAS to 70 DAS in plant and at harvest in grain & stover with concomitant increase in uptake of these nutrients over no FYM application. The crop under influence of 10 t FYM ha^{-1} accumulated higher quantum of nutrients (N, P and K) at harvest by 36.32, 38.86, 26.01 per cent estimated over their controls (Table 4.13 to 4.21).

Under the present investigation soil analysis after harvest of maize crop also validated positive impact of organic fertilization on enhancing nutritional status of soils. It is widely reported that during the process of microbial decomposition of added organic manure (FYM) several organic acids are released which results in reduction of soil pH and solubilize inherent soil nutrients thereby increase their availability from soil media along with their own nutrient constituents (Somani, 1983; Brady, 1996). Under the alkaline calcareous soils, higher amount of $CaCO_3$ reduces the availability of most of the nutrients, the organic fertilization plays a paramount role in such soils through process of chelation with the formation of humans coating on $CaCO_3$ and restricts its reaction with available nutrients in the soil thus led to greater availability of nutrients (Dahiya and Singh, 1980). Moreover, enhanced enzymatic activated due to increased microbial activities in soil media under organic fertilization plays a key role in transformation, recycling and availability of nutrients from soil (Singaram and Kumari, 1995). Besides favourable effects of FYM on various aspects of soil systems (physico-chemical and biological) the humic substances formed with addition of FYM enters into plant system and favorably effect on various physiological activities namely respiration, oxidation and reduction reactions by acting as a acceptor of H^+ ions. It also alters various enzymatic activities in plants such as peroxidase, catalase, etc. which promotes cells elongation, root and shoot growth and carbohydrate metabolism (Schnitzer, 1991).

In general improved nutritional status of plant parts under FYM application primarily seems to be on account of enrichment of these nutrient in soil, secondly it can be attributed to their efficiency extraction/translocation in the plant system due to enhanced activities of roots on account of pivotal role of FYM on maintenance of better physico-chemical and biological properties of the soils. The correlation studies also substantiate that enhanced availability of nutrients in soils had synergetic effect on nutrient content of plant parts. The results are in close conformity with the findings of Sharma *et al*. (1995); Ramamurthy and Shivshankar (1996).

Significant increase in uptake of nutrients (N, P and K) with the application of FYM seems to be due to the fact that uptake of nutrients in product of biomass accumulated by particular plant part and its nutrient content. Thus positive impact of organic fertilization on both these ultimately led to higher accumulation of nutrients. Significant relationship as shown by correlation coefficient between total uptake and total biomass also supports the above findings. Sharma and Saxena (1985) and Sharma and Gupta (1998) reported an increase in uptake of nutrients by maize crop when fertilized with FYM.

5.3.5 Available N, P and K status of soil

The status of available nitrogen in soil after harvesting of maize was lower than that of the initial status of the soil under all the treatment due to the fact that maize crop is a heavy feeder of nitrogen except 10 t FYM ha^{-1} application. However, FYM application increased available N, P and K in soil after harvest of maize as compared to no FYM treatment (Table 4.22 to 4.25). This could be attributed to the greater availability of N and P through FYM. The increase in N content was solely attributed to the decomposition of N bearing organic compounds in applied FYM. However, enhance in P availability was the combined effect of released organic acids and organic anions on the decomposition of organic matter as result of increased physiological and biological properties soil and reduces the activity of P complexing agent to make more P available to the crop due to FYM application (Dahiya *et. al.,* 1980). The released acid forms chelates with free AI^{3+} and Fe^{3+} responsible for P fixation, leaving behind the same as an available forms. While, organic anions were subjected to isomorphus substitution with phosphate ions bounded with hydroxy compounds of AI and Fe. Due to application of 10 t FYM ha^{-1} occurred constant release in the soil and increased K status in soil as compare to no FYM. Similar results were reported by Singh and Tomer, (1991) and Desmukh *et. al.,* (1996).

5.3.6 Economics of the crop

Critical examination of B:C ratio clearly evidenced the lowering down of this ratio with incorporation of FYM in the maize crop. The lowering down of the B:C ratio with incorporation of FYM in the present investigation may be attributed to the higher cost of this component with respect to inorganic nutrient sources (Table 4.26).

5.4 EFFECT OF FERTILIZER LEVELS

5.4.1 Growth parameter

The results show that application of 100% recommended dose of N, P and K i.e. 90, 30 and 30 kg ha^{-1} significantly improved growth parameters *viz*., final plant height, LAI (30 DAS to harvest), DMA (30 DAS to harvest), CGR (30 to 70 DAS), NAR (50-70 DAS) and LAD (30 DAS to harvest) of maize crop (Table 4.2 to 4.8). It is obvious that 100% recommended dose of NPK increased nutrient supply in Rhizosphere, which culminated into more absorption and higher uptake of nutrients (Table 4.16 to 4.21).

In general, over all improvement in growth of maize plants under the influence of increasing rate of fertilizer levels soil and plant environment conducive for better development of both morphological and biochemical components of the growth. The role of nitrogen in synthesis of protein, chlorophyll and other organic compounds of physiological importance are well established. Besides these, it has been widely documented that alike environmental factors, mineral nutrition particularly nitrogen plays an importance regulative functional role in plant system through synthesis and translocation of growth hormones which generally acts as stimulator for certain steps of growth and development. Further, phosphorus fertilization also improves the various metabolic and physiological processes in the plant system. It plays an important role in storage of energy and its transfer into plant system. The energy obtained from photosynthesis and metabolism of carbohydrates is stored in phosphate compounds (ATP) for subsequent use in growth and reproductive process through phosphorylation. In addition to this vital metabolic role, phosphorus is an important structural component of nucleic acid, phytin, phospholipids and enzymes. An adequate supply of phosphorus early in the life of a plant is important in laying down the premodia for its reproductive parts. It also increases the initiation of both first and second order rootlets and their development. The extensive root system helps in exploiting the maximum nutrients and water from soils.

Similarly, greater uptake of nutrients at harvest suggests their availability rise from vegetative stage and most of the nutrients are being translocated from vegetative parts. Thus, this assumption is well justified that higher nutrient status of plants under optimum fertilization is due to their greater availability in soil environment as well as their better extraction by the roots and thereafter translocation within the plant system. The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids, proteins and other growth promoting substances, which seems to have enhanced the meristamatic activity and increased cell division enlargement and their elongation resulted in higher plant height. In addition to protein synthesis, chlorophyll in leaves, which is primary absorber of radiant energy needed for photosynthesis. The improvements in morphological and biochemical parameters might have resulted in better interception and utilization of radiant energy leading towards higher photosynthesis and finally more dry matter accumulation by individual plant. The positive interrelationship between final dry matter per plant with plant height. The results of present investigation are in accordance with the findings of Singh and Kumar (1996); Tomer *et al.* (1997); Jat (1998); Mishra and Kurchania (2001).

The increase in leaf area index with application of fertilizer levels may be attributed leaf area (length and width of an individual leaf) as important effect of nitrogen is enhancement of leafy portion of the plant as shortage of nitrogen reduce leaf area expansion, enhance leaf senescence and alters canopy morphology. The improvement in morphological as well as photosynthetic parameter (LAI, CGR, NAR and LAD) might have resulted in better interception and utilization of radiant energy leading towards higher photosynthesis and finally more accumulation of dry matter of individual plant and the efficiency of radiation interception increased. Thus, experimental evidences on higher biomass accumulation clearly establish potential role of fertilizer in exploiting favourable environment towards formation of higher photosynthates by virtue of modifying most important photosynthetic component (LAI and LAD).

The correlation studies also indicate positive interrelationship between final plant height (r=0.924), LAI at 70 DAS(r=0.992), CGR between 50-70 DAS (r=0.920), NAR between 50-70 DAS (0.870) and LAD (0.989) improved final dry weight of plant (Table 5.1). The results of present investigation are in close conformity with findings of several researchers (Thakur and Singh, 1990; Singh and Kumar, 1995; Jat, 1998; Gangwar and Singh, 1992 and Nehra, 2001).

5.4.2 Yield attributes and yield

Increasing rates of fertilizer application from 50 to 100% RDF significantly improved yield attributes, namely cobs plant^{-1}, grains cob^{-1}, grain weight cob^{-1} and 1000-grain weight with concomitant increase in grain, stover and biological yields.

In the preceding section, it was well emphasized that increasing rates of fertilizer, markedly improved over all growth of crop in terms of dry matter production plant^{-1} by virtue of its impact on morphological and photosynthetic components along with accumulation of nutrients. This indicates greater availability of nutrients and metabolites for growth and development of reproductive structure, which ultimately led to realization of higher productivity of individual plant. The increased availability of nutrients and photosynthates might have enhanced number of flower and their fertilization resulting in higher number of grains cob^{-1}. Further, in most of cereals, greater assimilating surface at reproductive development results in better grain formation because of adequate production of metabolites and their translocation towards grain as evident from improvement in nutrient concentration and their uptake (Table 4.13 to 4.21). The results of present investigation are in close conformity with findings of Menaria (1987), Singh *et al*. (1995), Pandey (1998) and Jat (1998).

Significantly higher yield attributes taken into consideration for treatment evaluation and productivity measured in terms of seed, stover, biological yields were recorded with 100 % RDF over 50% RDF. The improvement in yield attributes might be due to higher availability of metabolites as reflect by significant relationship between DMA at 70 DAS and at harvest with cobs plant^{-1}, grains cob^{-1}, grain weight cob^{-1} and yield plant^{-1} (Table 5.1).

The positive response of NPK fertilization on yield could be ascribed to overall improvement in crop growth due to better nutritional environment, enabling the plant to absorb more nutrients as is evident from the enhanced content and uptake of nutrients. An increase in uptake of plant nutrients empowered the plant to manufacture more quantity of photosynthates, accumulating them in reproductive parts. The correlation studies have also validated the dependence of grain and stover yields of maize on uptake of nutrients by maize crops (Table 5.1). The significant increase in stover yield due to fertilizer application could be ascribed to its direct influence on dry matter production at all the stages of crop growth, while indirect influence seems to be on account of increase in plant height and green leaves plant^{-1}. The increase in stover yield might be due to significant relationship between N, P and K uptake under influence of fertility levels increased photosynthetic efficiency and nutrient uptake by crop (Table 5.1). Similar findings have also been reported by Madhavi *et al*. (1995), Jat (1998) and Brar, *et al*. (2000).

While, regression analysis also validated that unit increases in grain and stover yields increased biological yield by 2.501 and 1.618 q ha^{-1}, respectively. Further, increased biological yield with 100%, recommended dose of NPK seems to be on account of increased photosynthetic efficiency and greater development of vegetative structures *viz*. LAI, DMA plant^{-1} and CGR at harvest. Under the present study, regression analysis of growth parameter revealed that unit increase in LAI at harvest, DMA plant^{-1} and CGR between 70 DAS to harvest increased biological yield by 50.025, 0.523 and 3.290 q ha^{-1}, respectively. The results of present investigation are in close agreement with the findings of Shah *et al*. (1992) and Jat (1998).

5.4.3 Seed quality

Significantly higher protein yield was estimated under application of 100 per cent recommended dose of N,P and K. These improvements could be attributed due to greater availability of nitrogen, phosphorous and potassium applied. The pivotal role of N and P in protein synthesis is well documented, nitrogen is constituent of amino acids and basic unit of protein. The significant increase in protein yield seems to be increased in grain yield of maize. While, protein content not affected significantly due to fertilizer application i.e. 50 to 100% RDF (Table 4.12).

5.4.4 Nutrient content and uptake

Application of 100 per cent of recommended dose of fertilizers (NPK) significantly improved nutrient content N and P in plant at 30 DAS to harvest and in seed & stover and thereby reflected into their higher uptake by the crop (Table 4.13 to 4.15 and 4.16 to 4.21). The positive influence of fertilization on nutrient content at successive crop growth stages at 30 DAS to harvest and in seed & stover of maize crop appears to be due to improved nutritional environment both in root zone as well as in plant system. Increased availability of nutrients coupled with higher absorption by the plant (due to extensive and well developed root system) led to their deposition in vegetative parts at successive crop growth stages i.e. 30 to 70 DAS later on translocated to reproductive parts ultimately increased content in seed and stover yields. Significant improvement in uptake might be attributed due to their higher content in plant and associated with higher yield. Results of present investigation are in agreement with the findings of Singh and Kumar (1995); Jat (1998); Sharma and Gupta (1998) and Goel and Somani (2002).

The total uptake of N, P and K by maize was increased significantly due to fertilizer application (Table 4.16 to 4.21). It is an established fact that accumulation of nutrients is depended on their concentration at cellular level and dry matter production. Thus, application of N, P and K fertilizers enhanced growth and thereby ultimately led to higher accumulation of nutrients by plant parts along with total uptake by the crop. However, the uptake of N, P and K in grain, straw and total uptake increased with progressive increases in the supply of N,P and K to the crops because of higher availability of these nutrients and higher biomass yield. The results of present investigation are in close agreements with the findings of Menaria (1987), Singh and Kumar (1995) and Thakur *et al*. (1990).

5.4.5 Available N, P and K status of soil

The status of availability of N in the soil after harvesting of maize was lower than the initial status of the soil under all the treatment except 100% RDF (NPK) due to the fact that maize crop is a heavy feeder of nitrogen. At recommended dose of nitrogen, the crop growth was also better than their lower doses. So naturally more uptake of nitrogen took place under these treatments. However, the available status of phosphorus in the soil increased with increasing fertilizer levels. Significant improvement in status of P in soil was observed with increasing fertilizer levels might be due to build up of phosphorus in soil as a result of phosphorus addition. Besides on addition of phosphorus fertilizer to the soils, there might be some sort of triggering action on native soil P resulting in increased availability.

The NPK fertilizers improved and build up of soil available N, P and K. The significant build up of the soil available N due to NPK application could be attributed to adequate supply of N through fertilizer to meet the crop requirement.

Increasing level of fertilizer due to limited utilization of P by crop from the applied source, which resulted in building of soil phosphorus status (Kamalakumari and Singaram, 1996). The enhance status of K could be attributed to higher amount of potassium being added through murate of potash at maize harvest (Table 4.22 and 4.23 to 4.25).

5.4.5 Economics of the crop

Mean data for net returns and B:C ratio under the influence of fertilizer application indicated that highest net returns as well as B:C ratio with the treatment of 100% NPK through fertilizer were obtained as compared to the lowest values with 50% NPK. The reason is self-explanatory that 100% NPK responded maximum with respect to maize grain as well as stover yields resulting into maximum net returns (Table 4.26).

5.5 EFFECT OF BIOFERTILIZER

5.5.1 Growth parameter

The results indicate that at early stage of crop growth (30 DAS), seed inoculation either by *Azotobacter* alone or *Azotobacter* + PSB failed to influence LAI of maize crop but with the advancement in crop duration significantly enhanced LAI (50 DAS to on wards) by seed inoculation. However, net assimilation rate significantly influenced between 50-70 DAS but in later stages seed inoculation failed to prove significant improvement. While, seed inoculation either by *Azotobacter* alone or in combination with PSB significantly enhanced morphological parameters of growth viz. final plant height and LAD (30 DAS to harvest) consequently biomass per plant (30 DAS to harvest). At harvest the crop under the influence of seed inoculation of *Azotobacter* + PSB produce higher biomass 9.03 per cent as well as attained higher CGR between 50-70 DAS, NAR between 50-70 DAS compared to these parameters recorded under no inoculation, (Table 4.2 to 4.8). While, the regression analysis revealed that unit increase in LAI at 70 DAS, CGR (50-70 DAS), NAR (50-70 DAS) and LAD improved dry weight of plant by 71.083, 6.066, 7.205 and 40.958 g plant^{-1}, respectively.

The effectiveness of *Azotobacter* inoculation to provide congenial environment for proper growth and development of maize is ascribed to non-symbiotic nitrogen fixation. It is an established fact that micro-organisms (free-living bacteria) assimilate atmospheric nitrogen through enzyme nitrogenase in bacterial cells. The fixed organic nitrogen in becteroides in dissociated (decomposed) later on, and oxidized to nitrate (NO_3) form. The increased in endogenous nitrogen content due to inoculation might have promoted crop growth. The increased LAI due to availability of fixed nitrogen might have improved photosynthetic activity and production of more photosynthates resulting in higher dry matter production. The beneficial effect of *Azotobacter* inoculation on dry matter production was reported by Patil *et al*. (1992) and Singh *et al*. (1993). PSB failed to bring about significant improvement in growth parameters of maize. However, combined inoculation of *Azotobacter* or along with PSB increased the aforesaid growth parameters. The results of present investigation on over all improvement in crop growth due to combined inoculationof *Azotobacter* + PSB are in close accordance with Mounoz and Valdes (1995). Patidar (2000) and Jat (1998).

5.5.2 Yield attributes and yield

Seed inoculation with *Azotobacter* alone or in combination with PSB significantly improved in yield attributes *viz*., cobs plant^{-1}, grains cob^{-1} and grain weight cob^{-1}. The crop inoculated with aforesaid microorganisms produced significantly higher grain, stover and biological yields over no inoculation (Table 4.9 and 4.10).

The marked improvement in productivity of individual plant under the influence of *Azotobacter* inoculation seems to be an account of its profound effect on dry matter production along with accumulation of nutrients. Thus, greater availability of both these growth inputs might have maintained adequate supplies as per need of plants for yield formation. The increase in grain yield with *Azotobacter* inoculation could be attributed to its impact on improving productivity of individual plant. This could be ascribed to the fact that crop yield is a function of several yield attributing factors which are dependent on complementary interaction between vegetative and reproductive growth of crop. The existence of favourable nutritional environment under the influence of biofertilizers had a positive influence on both the phases of crop, which ultimately led to realization of higher yield. These findings are corroborating with that of Patil, *et al*. (1992), Mishra *et al*. (1996), Fulchieri and Frioni (1994) and Mishutin and Shilnikov (1971).

Biofertilizers, the microbial inoculations which bring about fixation of atmospheric nitrogen either in free living N_2 fixer in the rhizosphere (*Azotobacter*) or transform native unavailable phosphorus into plant utilizable form are low cost eco-friendly inputs for farmers. Result of present investigation (Table 4.10) show that use of these biofertilizers has significantly improved grain, stover and biological yield of maize. The improvement in yield of maize was limited when these biofertilizers were used singly (either N_2-fixers or phosphate solubilizing bacteria). However when N_2 fixers and PSB were used together there was significant additive effect. Such an additive influence of biofertilizers is attributable to biofertilizers used. Such mutually beneficial synergistic effect has also been reported by a number of workers (Gaur and Alagawadi, 1989; Tilak and Annapurana, 1993 and Totawat *et al*., 2000). Phosphate solubilzing bactera (PSB) not only solubilize organic and inorganic phosphorus in soil but also make available added phosphorus and thereby increasing P availability and improve the crop growth and yield (Gaur and Gaind, 1992).

5.5.3 Seed quality

Seed inoculation with *Azotobacter* alone or in combination with PSB significantly increased accumulation of protein content in grain. This increase in protein content seems to have increase in N content in grain, further significantly enhanced protein yield of maize. Significant increase in N content in grain could be attributed to fixation of nitrogen through biological nitrogen fixation by *Azotobacter* bacteria (Table 4.12). Similar, results are in conformity with the findings of Jain and Singh (2003).

5.5.4 Nutrient content and uptake

Nutrients (N, P and K) concentration in grain and stover were significantly influenced by biofertilizer inoculation. *Azotobacter* alone or in combination with PSB increased N content in grain and stover this might be attributed to greater availability of nitrogen through biological nitrogen fixation by *Azotobacter* bacteria. However, *Azotobacter* alone and combined inoculation of *Azotobacter* + PSB increased N and P content in plant at successive crop growth stages i.e. 30 DAS to at harvest as well as in grain and stover. The uptake of N, P and K increased with combined seed inoculation of *Azotobacter* + PSB (Table 4.13 and 4.14). Nutrients uptake is the product of yield and nutrient content, considerable increase in either nutrient content or in yield may increase the uptake. Since the content did not differ, therefore, the uptake was depended to mainly on yield. The dry matter yield (biological yield) increased as a result of over all improvement in crop growth and development due to biofertilizers resulting into increase N and P uptake (Table 4.16 to 4.19). The results are in close conformity with the findings of Saric *et al*. (1987); Pardes *et al*. (1988) and Das *et al*. (1997).

Observed significant increase in the uptake of nutrient, could be attributed to the fixation of nitrogen, better root growth due to increased availability of P by PSB besides secretion of growth promoting substances especially by *Azotobacter* (Totawat *et al*., 2000). The combined inoculation of nitrogen fixer and phosphate solubilzing microorganism benefited the plant better than either group of organism (Gaur and Alagawadi, 1989).

5.5.5 Available N, P and K status of soil after maize harvest

The available nitrogen status of soil after maize harvest was significantly increased with *Azotobacter* alone or in combination with PSB. However, the available P increased significantly with inoculation of *Azotobacter* alone or *Azotobacter* + PSB (Table 4.6 and 4.23 to 4.25). This might be attributed to greater non-symbiotic nitrogen fixation by *Azotobacter* and increase solubility of phosphate due to PSB inoculation. Available K was failed to increase under the microbial inoculation.

After harvest maize seed inoculation with *Azotobacter* alone or combined inoculation of *Azotobacter* + PSB reduced negative balance of N in soil as well as available P status also increased by combined inoculation of *Azotobacter* + PSB. While, *Azotobacter* alone not have more impact on K status but combined inoculation of *Azotobacter* + PSB improve 1.69 kg K ha^{-1} as compared to no inoculation (7.26 kg ha^{-1}).

5.5.6 Economics of the crops

Mean data for net return and B:C ratio clearly evidence that *Azotobacter* alone or co-inoculation with *Azotobacter* + PSB significantly increased the net returns and B:C ratio as compared to no inoculation. Seed inoculation of *Azotobacter* + PSB responded to maize grain and stover yields resulting into maximum net returns and B : C ratio (Table 4.26). results are close conformity with the findings of Mishra, *et. al*. (1995), Suri, *et. al*. (1996) and Nanda, *et al* (1998).

6. SUMMARY

A field experiment entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** was carried out during *kharif* 2001 and 2002 at KVK, Bhilwara (Rajasthan). The experiment was laid out in split plot design comprising one main plot control, three FYM levels (0, 5, 10 t ha^{-1}), three fertilizer levels (50, 75 and 100% RDF) were in main plot and three biofertilizers (control (no inoculation), *Azotobacter* and *Azotobacter* + PSB) in sub plot. Thus, making 10 treatments in main plot (3 OMx 3 Chem ferti +1Main plot control) and 3 in sub plot. However, main (10) x sub plot (3) make 30 treatment combinations, which were replicated thrice. The results presented and discussed in the preceding chapters are summarized below:

6.1 EFFECT OF TREATMENTS

- Maximum plant height recorded due to treatment application and increase by 18.14 per cent over control. However, maximum dry matter accumulation at different successive crop growth stages recorded due to treatment application and increases were in tune of 60.57, 57.99, 44.25 and 51.36 per cent at 30, 50, 70 DAS and at harvest over their controls, respectively. Treatment application also influenced significantly different growth parameter *viz*., LAI, CGR, NAR and LAD at all successive crop growth stages.

- Application of treatment significantly improved yield attributes *viz*., number of cobs $plant^{-1}$, number of grains cob^{-1}, grain weight cob^{-1} and 1000-grain weight over their controls. Grain, stover, biological yields and harvest index also followed same trend with treatment application and increases were by 54.68, 36.99, 42.05 and 9.08 per cent over control, respectively. Protein content and protein yield were recorded maximum due to treatment application and increased by 6.09 and 66.93 per cent over control.

- Nitrogen content in maize plant at 30, 50, 70 DAS and at harvest in grain & stover were significantly improved by treatment application. On mean basis, the percent increases due to treatment application in N content over control were 5.31, 7.10, 9.56 per cent at 30, 50, 70 DAS and 7.98 and 7.22 per cent in grain and stover, respectively.

- Phosphorus content in maize plant significantly enhanced due to treatment application at all crop growth stages. On mean basis, percent increase in P content by 5.78, 6.25 and 5.15 at 30, 50, 70 DAS and 7.57 and 13.51 per cent in grain and stover at harvest, respectively. But in case of potassium content it was significantly improved in grain and stover by 5.72 and 4.62 per cent over no FYM, respectively.

- N uptake significantly enhanced at successive crop growth stages and at harvest by treatment application. Consequently the crop under aforesaid treatment level drained highest quantum of nitrogen 10.40, 4.01, 97.88 and 110.26 kg ha^{-1} indicating the increase of 69.66, 71.88, 61.36 and 55.95 per cent more over that accumulated under main plot control.

- Application of treatment significantly increased accumulation of highest amount of P in plant over control. On mean basis, P content increased by 69.92, 71.00, 55.03 and 65.68 per cent at 30, 50, 70 DAS and at harvest as compared to control. While, under treatment application K uptake significantly increased at successive crop growth stages i.e. 30 DAS to harvest. On mean basis, K uptake increased by 57.27, 63.28, 50.37 and 44.50 per cent at 30, 50, 70 DAS and at harvest.

- Application of treatment significantly improved soil available N, P, K and organic carbon% after harvest of maize and estimated under treatment application were 253.18 kg N, 25.30 kg P_2O_5 and 353.66 kg K_2O and 0.416 organic carbon content, respectively.

- Maximum net return and B:C ratio Rs.13440/- and 1.74, respectively were obtained under 100% RDF as compared to control (net returns Rs. 9771/- and B:C ratio 1.59).

6.2 EFFECT OF FYM

- Among the level of FYM 10 t ha^{-1} significantly improve the final plant height by 10.27 per cent over no FYM. Like wise crop accumulated significantly higher biomass $plant^{-1}$ with 10t FYM application at successive crop growth stages i.e. 30, 50, 70 DAS and at harvest over 5 t FYM and no FYM, respectively.

- Application of 10 t FYM ha^{-1} significantly improved LAI and LAD (dm^2 day^{-1}) at all crop growth stages and harvest. While, CGR significantly enhanced upto 70 DAS but in later, its application failed to influence at 70 DAS to harvest. However, NAR (50-70 DAS) significantly promoted with 10 t FYM ha^{-1} application but between30-50 DAS and 70 DAS to harvest failed to respond FYM application.

- Application of 10 t FYM ha^{-1} recorded significant improvement in cob $plant^{-1}$, grains cob^{-1}, grain weigh cob^{-1} and 1000-grain weight with concomitant increased in grain, stover and biological yields by 43.89, 20.10 and 20.64 per cent over no FYM application, respectively. However, harvest index significantly increased with 10 t FYM as compared to lower doses.

- Protein content in grain and thereby protein yield was significantly improved by application of 10 t FYM ha^{-1}. On mean basis, protein content and protein yield enhanced by 4.73 and 50.69 per cent over no FYM, respectively.

- Manuring with 10 t FYM ha^{-1} analytically enhanced nutrient (N & P) concentration in plant at 30, 50, 70 DAS and at harvest in grain and stover, while, failed to increase K concentration either plant or in grain and stover.

- Application of 10 t FYM ha^{-1} significantly increased uptake of N, P and K at successive crop growth stages i.e. 30 DAS to harvest. Two years mean data indicate that total uptake of N, P and K at harvest improved by 36.32, 39.32 and 26.01 per cent over control, respectively.

- Available nutrient status of soil after harvest of maize crop indicated that soil available N and P increase by 6.50 and 11.52 per cent under 10 t FYM ha^{-1} applied plots over their controls. However, organic carbon (%) status in soil was also improved and recorded 0.418 as compared to control (0.414).

- Application 10 t FYM ha^{-1} significantly increased net monetary net return of Rs. 17431 ha^{-1} as compared to no FYM (Rs. 12725 ha^{-1}) but in case of B: C ratio increasing levels of FYM were at par to each other.

- **6.3 EFFECT OF FERTILIZER LEVEL**

- The successive increase in fertilizer levels from 50 to 100% RDF failed to cause significant variation on plant population recorded at 20 DAS and at harvest.

- Application of 100% RDF significantly increased final plant height. On mean basis 100% RDF increased plant height by 8.17 per cent over 50% RDF. However, dry matter accumulation significantly improved with increasing levels of fertilizer from 50 to 100% NPK at all successive crop growth stages. On mean basis DMA $plant^{-1}$ increased by 18.52, 18.78, 15.04 and 12.90 per cent at 30,50.70 DAS and at harvest over 50% RDF. Further, application of 100% RDF significantly enhanced LAI at all successive crop growth stages over 50% RDF during course of study.

- CGR (0-30, 30-50, 50-70 DAS) and NAR (50-70 DAS) significantly improved under 100% RDF. However, NAR between 30-50 DAS and 70 DAS to harvest failed to respond with fertilizer application. Application of 100% RDF significantly increased LAD at all successive crop growth stages (30 DAS to harvest). However, 75% RDF significantly improved LAD between 50-70 DAS and 70 DAS to harvest. Further, increasing levels of fertilizer from 50 to 100% RDF significantly enhanced LAD (integral mean value of LAD).

- All fertilizer doses failed to influence 1000-grain weight and harvest index, while 100% RDF significantly increased cobs plant^{-1}, grains cob^{-1}, grain weight cob^{-1} consequently grain, stover and biological yields. The increases were by 19.73, 12.46 and 14.23 per cent over 50% RDF.

- Successive increase in fertilizer levels from 50 to 100% RDF failed to improve protein content in grain but protein yield significantly increased with 75 and 100% RDF over 50% RDF. However, aforesaid dose of fertilizer increased protein yield by 14.42 and 22.67 per cent over 50% RDF, respectively.

- Increasing levels of fertilizer from 50 to 100% RDF failed to improve nutrient (N, P and K) concentration in plant at 30 to 70 DAS and at harvest in grain and stover. While, uptake of N,P and K significantly increased with 75 and 100% RDF over 50% RDF. Two years mean data indicate that crop drained highest quantum of nutrient N, P and K (119.20 kg N, 18.38 kg P and 117.88 kg ha^{-1}) under 100% RDF.

- Fertilizer levels i.e. 50 to 100% RDF failed to improve available N, K and organic carbon (%) status of soil after harvest of maize. While, P build up by 8.86 per cent more under 100% RDF as compared to 50% RDF.

- In corporation of 100% RDF significantly enhanced net monetary returns and B:C ratio of Rs. 16244 ha^{-1} and 1.81, respectively as compared to lowest net returns of Rs. 13334 ha^{-1} and B:C ration of 1.60 with 50% RDF. While, value of net returns and B:C ratio obtained by 75% RDF was at par with 100% RDF.

6.4 EFFECT OF BIOFERTILIZER

- Seed inoculation with *Azotobacter* alone or in combination with PSB did not produce any difference in plant stand at 20 DAS and at harvest. While, inoculation of maize seed either by *Azotobacter* alone or in combination of *Azotobacter* + PSB enhanced final plant height and DMA plant^{-1} at all successive crop growth stages i.e. 30 DAS to harvest. On mean combined inoculation of *Azotobacter* + PSB increased DMA plant^{-1} by 12.14, 14.34, 10.41 and 9.03 per cent at 30, 60, 70 DAS and at harvest over their controls, respectively. Further, seed inoculation failed to enhance LAI at early stage (30 DAS) but in later LAI significantly increased at 50, 70 DAS and at harvest by combined inoculation of *Azotobacter* + PSB over control.

- Growth parameters *viz.*, CGR and LAD increased significantly by seed inoculation either *Azotobacter* + PSB at all successive crop growth stages i.e. 30 DAS to harvest. However, NAR (50-70 DAS) significantly influenced by seed inoculation either *Azotobacter* alone or in combination with *Azotobacter* + PSB.

- Seed inoculation with *Azotobacter* alone or in combination with PSB significantly enhanced yield attributes namely cobs plant^{-1}, grains cob^{-1} and grain weight cob^{-1} but failed to improve 1000-grain weight. While, *Azotobacter* alone and co-inoculation with PSB were at par with each other.

- Grain, stover and biological yields improved significantly due to seed inoculation with *Azotobacter* alone or in combination of *Azotobacter* + PSB. On mean basis, magnitude of increases were to the tune of 12.80, 13.58 and 14.45 per cent with combined inoculation of *Azotobacter* + PSB and 8.80, 9.64 and 9.64 per cent with *Azotobacter* alone, respectively over their controls (26.47, 63.79 and 90.17 q ha^{-1}). While, *Azotobacter* alone and combined inoculation of *Azotobacter* + PSB were at par with each other.

- Protein content in grain improved significantly by combined seed inoculation of *Azotobacter* + PSB. Further, seed treatment with *Azotobacter* alone or in combination with PSB significantly enhanced the protein yield. On mean basis, seed inoculation with *Azotobacter* alone and combined inoculation of *Azotobacter* + PSB both were improved protein yield in tune of 11.12 and 16.31 per cent over no inoculation.

- Seed inoculation with *Azotobacter* alone or in combination with PSB significantly increased N content (at 70 DAS, in grain and stover) and P content (50, 70 DAS and at harvest in grain and stover). While, seed inoculation failed to improve K concentration in plant during the crop period.

- Seed inoculation either by *Azotobacter* alone or in combination with PSB enhanced significantly N,P and K uptake at all successive crop growth stages i.e. 30, 50, 70 DAS and at harvest. The highest value of N, P and K uptake were recorded under *Azotobacter* + PSB treatment.

- Available P status of soil after harvest of maize crop improved significantly with combined seed inoculation of *Azotobacter* + PSB. While, N, K and organic carbon (%) status value at par with no inoculation.

- Seed inoculation with *Azotobacter* alone or in combination with PSB significantly increased net returns and B:C ratio over control. On mean basis maximum value of net monetary returns and B:C ratio obtained of Rs. 15660 ha^{-1} and 1.87, respectively with combined inoculation of *Azotobacter* + PSB and lowest values of net returns obtained Rs. 12915 ha^{-1} and B:C ratio of 1.55 with no inoculation.

7. CONCLUSION

On the basis of results obtained from the present investigation entitled **"Effect of integrated nutrient management on productivity of maize (*Zea mays* L.) in south-east Rajasthan"** under prevailing agroclimatic conditions of Zone IV a (Sub-Humid Southern-Plain and Aravalli hills) revealed that combined application of FYM, chemical fertilizer and biofertilizer proved better for enhancing the productivity of maize.

- Application of 10 t FYM ha^{-1} with 100 % RDF along with seed inoculation of *Azotobacter* + PSB gave maximum grain and stover yields (38.67 and 86.16 q ha^{-1}) followed by 10 t FYM ha^{-1} with 75% RDF along with dual inoculation of *Azotobacter* + PSB produced grain and stover yields 37.86 and 83.75 q ha^{-1}, respectively.

- Based on economic viable treatment conclusion can be drawn that treatment combination of 10 t FYM ha^{-1} + 100% RDF along with combined seed inoculation of *Azotobacter* + PSB was found most remunerative and obtained maximum gross (Rs. 29875 ha^{-1}) and net (Rs. 19640 ha^{-1}) returns followed by 10 t FYM + 75% RDF along with seed inoculation of *Azotobacter* + PSB with gross and net returns of Rs. 29186 and Rs. 19315 ha^{-1}, respectively.

- Highest B: C ratio (1.96) was recorded under the combination of 10 t FYM + 75% RDF + seed inoculation of *Azotobacter* + PSB followed by 10 t FYM + 100% RDF + seed inoculation of *Azotobacter* + PSB with B: C ratio 1.92.

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